

USING NEURAL NETWORKS FOR FACIAL SENTIMENT ANALYSIS

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Declaration

I hereby certify that this material, which I now submit for assessment on the programme of study leading to the award of **B.Sc in Computing** in the Institute of Technology Blanchardstown, is entirely my own work except where otherwise stated, and has not been submitted for assessment for an academic purpose at this or any other academic institution other than in partial fulfillment of the requirements of that stated above.

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Abstract

Acknowledgements

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Abbreviations

ANN	Artificial Neural Network
CNN	Convolutional Neural Network
DBN	Deep Belief Networks
LSTM	Long Short-Term Memory
ReLU	Rectified Linear Unit
RNN	Recurrent Neural Network
ML	Machine Learning
NLP (1)	Neuro-Linguistic Programming
NLP (2)	Natural Language Processing

Chapter 1

Introduction and Background

The field of artificial intelligence and machine learning has become exponentially prominent in recent years. From business to social media, machine learning algorithms are being used to change the definition of efficiency and user experience. For example, machine learning algorithms are utilised by many large companies optimize the experience with image and voice recognition and photo searching (Deshpande, 2016). Companies such as Tesla Motors use computer vision for their self-driving automobiles, video sharing sites such as Youtube use machine learning to optimize the users preferred recommended videos and in some cases, it is even used in by medical companies for detecting cancer in patients. For example, convolutional neural networks (CNN's) have been used by researchers for brain tumor segmentation (Havaei et al., 2015). The use of CNN's proved to be an appropriate method for tumour segmentation as the results can be given from a range of 25 seconds to 3 minutes (Havaei et al., 2015). Artificial neural networks have been used by radiologists for Computer-Aided detections systems (CAdE) and Computer-aided Diagnosis systems (CAdx) to improve the accuracy of diagnoses, early detections and to minimize the time spent on evaluation by doctors (Firmino et al., 2014). Many businesses even depend on artificial neural networks for their business model as they can be applied to many industries and disciplines. According to Bhargava and Gupta (2017) artificial neural networks are used in a range of business applications such as forecasting of sales, classification of spending patterns, market targeting, risk analysis and bankruptcy prediction, to name a few.

Thus, considering the benefits and implications that these approaches have, the proposed project aims to illustrate how artificial neural networks work, with the use case of performing facial sentiment analysis for a retail environment. This paper is made of several chapters covering the literature of the field of neural networks, an analysis chapter which will delve into the background and high level specifications of the project and a system design and implementation. Furthermore, testing an evaluation results will be covered and a discussion about the overall project and work carried out.

Chapter 2

Literature Review

2.1 Analyzing and Detecting Employee's Emotion for Amelioration of Organizations

Subhashini and Niveditha make the opening statement that emotions usually do not take any place in a work environment in current society. Although the expression of feelings is suppressed in places of work, they suggest that emotions can affect five major areas in competitive advantage. The five given aspects of competitive advantage are as follows: Intellectual Capital, Customer Service, Organizational Reactivity, Production, Employee appeal and retentivity (Subhashini and Niveditha, 2015). In order to counter this apprehensiveness to expression of emotions in the work place, Subhashini and Niveditha suggest the concept of a facial emotion tracking system that will map the facial expressions of an employees face as they enter the company building.

The system architecture given by Subhashini and Niveditha briefly describes logistics of the program. Most employees entering a building to an organization must swipe a card to clock into the work hours. They suggest that they have designed a new system that removes the need for card swiping, by performing facial recognition. Not only this, but the system also implements emotion detection. The employee looks into a camera that will prove their presence in the building but will also perform some emotion detection. The system was implemented in the C Sharp programming language and uses skin tone segmentation to detect

facial features. The binary image is then converted to an RGB image and an inspection of every individual pixel is performed. If the RGB value is greater than 110, then the pixel colour is refactored to be a white pixel, otherwise it becomes a black pixel. This is done to make it easy to detect facial features in the video stream (Subhashini and Niveditha, 2015). Once detected, the image around the face is cropped. They then apply a Bezier Curve to the regions around the lips and eyes of the person being analyzed. The results of the person's identity and emotional status are then stored within a database. They conclude their paper by explaining that this system can be used by management to gain an understanding of their employee's sentimental state.

2.2 Deep Learning for Video Classification and Captioning

Wu et al.'s paper provides an in-depth analysis on the methods for video classification and video captioning in terms of deep learning. They claim that because of the exponential growth in internet bandwidth and computing power, video communications are becoming more and more prevalent, therefore paving the way for new video understanding applications (Wu et al., 2016). They make reference to current implementations to prove the growth of interest in the field of computer vision and video analysis, notably the ImageNet challenge.

Move over, they go on to give brief description of the two "deep learning modules" that have been used for visual analysis: Convolutional Neural Networks (CNN) and Recurrent Neural Networks (RNN). It is explained that LeCun et al. that developed LeNet-5 made a break through when they developed a CNN using the Back-Propagation Algorithm. But its noted that this is limited in performance when the complexity of the tasks is increased. Deep belief networks were developed to train networks in a unsupervised manner in order to counter this problem (Wu et al., 2016). AlexNet, a CNN proposed by Krizhevsky et al. in 2012, introduced two way to increase the performance of CNN's using the Rectified Linear Units(ReLU) activation function and dropout to decrease overfitting (Wu et al., 2016).

Secondly, RNN's are brought forward. Wu et al. explain the difference between CNN's and RNN's, stating that CNN's are all feed forward networks that do not use cycling, which can prove be disadvantageous when working with sequence labeling. Two issues can occur with RNN's: Vanishing Gradient and Exploding Gradients as short term memory is used when cycling through the network. The solution given to this is an RNN variant called Long Short-Term Memory (LSTM).

2.2.1 Image-Based Video Classification using CNN's and LSTM's

They state that Karparthy et al. researched the common architectures for learning spatial-temporal clues in large video datasets. It appeared that models using single frames as input achieve similar results as models using stacks of frames. From this, Simonyan and Zisserman proposed the idea of the Two-Stream Approach, because of the cost effectiveness and time consumption that come with training 3D CNN's. This Two-Stream approach involves training the CNN on single and stack frames concurrently. Both outputs are put through a score fusion. The result is the weighted sum of both scores (Wu et al., 2016).

Although Two-Stream is a good approach, it is not sufficient as it is not capable of dealing with long video clips. Therefore, LSTM's are utilized as they do not suffer from the problem of vanishing gradients. It has been found that CNN's and LSTM's compliment each other when working in conjunction with each other (Wu et al., 2016). They conclude their paper with a summary of the written topics about, regarding the growth for the need for video understanding applications, the used of CNN's and RNN's, in addition to the variants of these deep learning modules.

2.3 Subject independent facial expression recognition with robust face detection using a convolutional neural network

As stated by Matsugu et al., difficulties may arise with facial recognition. In terms of a face being in a smiling-like state, could have different implications. As well as this, a facial recognition system should be able to work with a wide range of variability of faces. They then give some examples of past implementations such as facial recognition with rigid head movement by Black and Yackoob in 1995, and speak about how this does not meet the requirements of dealing with wide variance. A rule based system is proposed (Matsugu et al., 2003). With their model, layer trains on a module-by-module (module being the nose, eyes, mouth etc) basis. Meaning each layers train on a certain facial feature. Each of the neurons perform an averaging of some local receptive fields then they use a skin tone detector to detect each module on the face (Matsugu et al., 2003). For training, Layer one and layer two are trained for 8 modules using back propagation. Layer three and four train on more complex feature detectors such as the mouth and eyes. The output is then sent to the rule based algorithm for handling variability and robustness.

The rule based algorithm takes the output of the CNN and measures the distance between the features. From these calculation, the rules are applied to determine if the person is in a laughing or smiling state. The rules are summarised as follows (Matsugu et al., 2003):

- The distance between eyes and lip get shorter.
- The horizontal length of lip gets longer.
- The eyes wrinkle.
- The gradient of lip from the end point to the end point increases.
- Detection of teeth increases.
- The edges (wrinkles) of cheek increase.

In conclusion, they received a 97.6 percent accuracy for 10 test subjects with 5600 images. They assert that their model is significantly more efficient as they only require one CNN due to their rule based algorithm, in contrast to Fasels implementation that uses two CNN's working in synergy with one another.

2.4 Neuromarketing - The Art and Science of Marketing and Neurosciences Enabled by IoT Technologies

A paper by Arthmann and Li describes the growing field of Neuromarketing with an opening statement: Advertisers recognise that there is a relationship between stimulating the emotions of a customer and influencing their actions. Online shopping has drastically affected the store sales, and it is also explained that more than 3500 stores have shut down due to bankruptcy in 2017 (Arthmann and Li, 2017). Their answer to this change in buying is Neuro Linguistic Programming(NLP). Neuro Linguistic Programming, not to be confused with natural language processing, is a method of observing the verbal and non-verbal communication of humans. Eye accessing cues (eye movements) are said to be linked to certain emotions or thoughts. Neuromarketing incorporates NLP and IoT devices to understand the consumer sentiment more extensively. Neuromarketing aims to remove marketing biases by utilizing the consumers subconscious. One example given by Arthmann and Li is the notion of facial coding and motion tracking, which is put in place to determine why consumer make certain decisions. Furthermore, they make their belief clear of retailers benefiting from this when it is put forward that artificial intelligence and machine learning will evolve, giving better results of consumer preference shifts. Additionally, these neuromarketing systems can replace thermoimaging people counting devices that clock people walking into stores that may not be eligible customers (children). Further examples are provided for these technologies. They go on to describe a scenario when a customer is given an image of a product and a price in front of a webcam, and by performing facial coding and sentiment analysis, we may get a better sense of what the consumer is feeling. Arthmann and Li conclude their paper by

declaring the future potential of these systems using when integrated with "always on" IoT technologies.

2.5 Facial expression recognition with Convolutional Neural Networks: Coping with few data and the training sample order

Lopes et al. open their paper by explaining the definition of facial expression. They describe it as facial changes that occur with someone due to emotional state or social communication. In terms of facial expression recognition software, a lot of systems give misleading accuracy results due to the overlapping of training and test data. They explain that some problems may occur. For example: dealing with ethnicity and variability of faces. Their response to this is training with one data set and testing with another to provide more accurate results (Lopes et al., 2017). They make reference to Liu et al's work on facial recognition by describing the three stages of training: Feature learning, which is responsible for extraction of all facial features. Secondly, Feature Selection, that selects the best features to learn. And lastly, the classifier, that each expression has one specifically allocated to. Lopes et al. then move on to explain convolutional neural networks (CNN) on a high level. Firstly, the CNN is comprised of a convolution layer, that if given a kernel size. This kernel shifts over the image given to generate a map. This is followed by sub-sampling. Sub-sampling is used to reduce the map size to increase the accuracy in variance. Lastly, the fully-connected layer is introduced. This is a neural networks that has fully-connected neurons to it's previous layer (Lopes et al., 2017). They explain that of all the facial recognition methods, CNN's prove to be the most advantageous because they can use raw image data input for an accurate prediction.

A related work section is then brought forward to explain similar models that have been developed. Much progress has been made in the field of neural networks have come about in recent years. This is due to advances in GPU technologies and computing power Lopes et al. (2017). One example of relevant work they provide is the work done by Song et al., in which

a CNN was developed for a mobile phone application for facial expression recognition. This CNN used image augmentation techniques, due to the lack of public data for their network, to prevent over-fitting. This increases the amount of data available for training the network (Lopes et al., 2017). Song et al. received an accuracy of 99.2 percent using the CK+ dataset. A CNN with 15 layers was developed by Burkert et al that achieved similar result, of 99.6 percent. They point out that although this network achieved high results, they may prove to be misleading as it is not made clear that their training and test datasets were different (Lopes et al., 2017). They then go on to compare the related works by expressing the flaws of using over-lapping data and the lack of emotion expressions classified.

2.5.1 Facial Expression Recognition System

Following the introduction and related work, Lopes et al. provide a prerequisite understanding for their model. The implementation of their model has two stages: the training stage and the testing stage. The training stage consists of a few preliminary steps. Firstly, new images are made from existing ones in the dataset to increase the trainable data. This is done using a method proposed by Simard et al. called "synthetic sample generation", which involves rotating and skewing the existing images. For every photograph that exist, an additional 70 are made, adding noise to the data. This synthetic data is only used in the training stage and advantageous as it allows the model to handle variance in an image (Lopes et al., 2017). Secondly, to address the problem in alignment with facial features, the notion of rotation correction is introduced that aligned the images using the eyes as the horizontal axis. Image cropping is then used to reduce the amount of background noise as it is said to decrease the accuracy and overall performance of the CNN. This is done by detecting only features that are valid of expression classification and cropping the image around them, excluding the neck, ears and background from the image. Down sampling is then applied for reducing the size of the image, making it 32 x 32 pixels in size. Brightness and contrast can cause problems with images, therefore intensity normalisation is applied to lower these aspects of the image (Lopes et al., 2017).

As for the testing stage, the same methods are used as the training stage. The CNN outputs the predicted emotional expression with the following number ID's:

- 0** - Angry
- 1** - Disgust
- 2** - Fear
- 3** - Happy
- 4** - Sad
- 5** - Surprise

Their model is comprised of 2 convolution layers, 2 sub-sampling layers and 1 fully-connected layer. The sub-sampling layers use max pooling with a 2x2 kernel. This halves the size of the image. The fully-connected layer consists of 256 neurons and provides 6 prediction outputs. Stochastic gradient descent is applied for back propagation and the Loss is calculated using soft-max. They also use the rectified linear unit (ReLU) for their activation function.

2.5.2 Experiments

Lopes et al.'s experiments include a number of different test cases. These test cases utilize the CK+ database that has images of a hundred students ages from 18 to 30. An average accuracy is given for each of the test cases. See table 2.1 on page 11 for results.

Test Case Averages	
Test Case	Average
no pre-processing	53.57%
just cropping	71.67%
just rotation correction	61.55%
cropping and rotation	87.86%
intensity normalisation	57%
both normalisations	86.67%
spatial normalisation and synthetic data	87.1%
both normalisations and synthetic data	89.76%

Table 2.1: Test cases by Lopes et al.

In summary, it can be seen from the table above that by applying the synthetic and normalized data to the training dataset, a higher accuracy can be achieved when testing.

2.6 Relevant Work and Critical Analysis

Subhashini and Niveditha, 2015's work on analyzing and detecting employee's emotions for organizations ties in very well with the proposed project as it involves using sentiment analysis on subject to gain an underlining understanding of their emotions that may or may not be expressed verbally. The main research goal was to achieve employee identification in conjunction with facial emotional analysis and they were successful in execution. They used a Bezier Curve on the subjects lips and eye to detect the emotion expressed by analysing the gradient of the curve. However, although this paper proved that the project was a success, there are some inconsistencies. For example: in the related work, they do not explain how the work is related and only give titles. Secondly, the results show no code snippets or pseudocode to explain the implementation of the system. Only screen shots of the user interface are provided. Furthermore, there are more absences of proof. The paper is lacking statistics and graphs to display the accuracy metrics or progress of the systems performance. There are some bold statements used that are not back up by citatins like when it is said that "emotions were considered a forbidden topic in the working place". Despite these weak areas in the paper, a good aspect of this system is the use of real life subjects used in testing.

The review of Deep Learning for Video Classification and Captioning by Wu et al. provides an in depth look into the aspects of different neural networks and what are they strong and weak points. The motivation for their research is driven by their claim that video communications is growing and that there needs to be better applications for video understanding. The relevancy of this paper provides the concept of the "Two-stream" architecture. Although it is not planned to develop two convolutional neural networks (CNN), it may be sought after to develop a score fusion algorithm, similar to the one mentioned in this paper. This paper is very in depth and draws good comparisons between the different techniques that can be used for video classification. Despite the quality of this paper, some aspects need improvement. There is heavy usage of words like "we" used. Also, some statements are made by (Wu et al., 2016) that are not cited to support their claim. This is evident when it is said "As deep learning for video analysis is an emerging and vibrant field..." (According to whom?).

Subject independent facial expression recognition with robust face detection using a convolutional neural network by Matsugu et al. illustrates the difficulties that may arise when performing facial recognition. They highlight the problems that may occur in terms of being able to handle variability of subject faces, and certain angles. Their approach to this problem is addressed by implementing a rule based algorithm that analyzes the results given from the CNN. Furthermore, their model is designed to be segmented and be trained on specific facial features instead of the face as a whole. Their model proves to be a success as they score an accuracy of 97.6 percent, also they do not require a second CNN working concurrently to achieve similar results as other models have done so previously, which can be cost effective. Some similarities arise between this paper and the proposed project, they both use sentiment analysis and require the ability to handle a wide range of variability. This proves beneficial to the proposed project as it provides inspiration to use a rule based algorithm for determining emotions. Even though this paper is well written, there are some issues. In certain parts there are abbreviations to words given without the full word being given prior which can cause confusion to the reader. For example: "FP neurons". In addition to this, their model is specific for smiling faces and doesn't accommodate for other emotions, which should be at least

provided in a further work section.

Arthmann and Li's paper titled *Neuromarketing The Art and Science of Marketing and Neurosciences Enabled by IoT Technologies* is a promising insight to the field of neuromarketing. They recognize the association of online shopping and loss of sales for retail stores, and give example of how neuro-linguistic programming and IoT technologies can be used as a combination to understand their customers un-explicitly expressed emotions. Furthermore, it's heavily argued that the integration of AI and machine learning will evolve this concept to understand the thoughts of consumers and further tackle loss in productivity. This proves relevant to the proposed project as it is a very similar use case. They both aim to gain a deeper understanding of human sentiment that may not be express verbally. Although this is possibly the most interesting paper of this review, it is severally lacking citations. Also, there are a lot of assumption brought forward with no clear indication as to how this knowledge is known. Additionally, it is also assumed that people will adopt these "always on" IoT devices and agree for their physical aspects to be used for consumer targeted marketing.

Lopes et al. go into great detail of the past implementations of facial recognition systems. They review a number of methodologies to reinforce the idea of data augmentation with their own work. It is stated that due to the lack of datasets that are publicly available and overlapping of data, much of the accuracy results that are given by past works may be inaccurate (Lopes et al., 2017). Furthermore, they enable the reader to grasp a deep understanding to not only how convolutional neural networks operate, but how the common methods of implementation should be done. This is evident when explaining their system's implementation which was broken into two segments: The training phase and testing phase. Additionally, they give a clear and comprehensible description of the methods chosen and why they were taken. For example: using synthetic sample generation, rotation, cropping, down sampling, and normalization. This work proves relevant to the proposed project as it gives an explanation of how a segment of the project should be made. Also, Lopes et al. make it very clear that the CK+ dataset is the most suited dataset for facial and sentimental expression recognition.

2.7 Concluding Remarks of Literature Review

In conclusion, the five papers reviewed topics in relation to convolutional neural networks, facial sentiment analysis, emotion detection and current applications in the real world. Relevant aspects include detecting employees emotions in a work environment, implementing a score fusion algorithm for achieve a summation of two sentiment detecting technologies, the idea of segmenting facial features while training to accommodate for variance and the notion using human emotion understanding for a business solution. Lastly, an indication to what data that should be utilized is obtained throughout the range of papers that have been reviewed.

Chapter 3

Analysis

The following chapter will provide the business background of the project and further justification for such a system to be implemented, an analytic insight to the steps required for designing the proposed software in relation to a business use case, identify some of the problems that may arise and outline objectives for implementation.

Project Background

An article by Hague and Hague for the B2B international states that understanding a customers satisfaction rate is important as it can show where the business is doing well or where it needs improvements. It also can give indication to business owners where a further staff training is needed, or how there may be a need for cultural change. In light of this, seeing your business through the eyes of the customer can provide understanding of its downfalls. This in turn prevents more customer churn and can prove to be financially beneficial (Hague and Hague, 2017). They state that the downfalls of customer service surveys is that the survey must "ask the right question of the right person". Hague and Hague give two reasons why this is difficult: they may know what to ask the customer in respect to their specific interaction with the business, also they may not have the contact details of the customer to further inquire into satisfaction of the individual. A main reason why customer surveys result may be misleading is the fact that an average of only 10% percent of online

surveys sent to customers are responded to, meaning that these results are not representative of an entire customer base (Willott, 2011) . Furthermore, surveys are described by Hague and Hague as a "snapshot at one point in time", and do not accurately represent the feelings of the customer during transaction process, and measuring the satisfaction of customers should "be a continuous process".

Kirkpatrick describes the use of artificial intelligence technologies in customer service as a beneficial factor for businesses, as it can automate the tasks that are "too time consuming". In consideration of the aforementioned problems in the customer service sector, the proposed technologies aims to eliminate the process of requesting customers to fill out surveys by performing a facial sentiment analysis during the transaction, and in turn reduce cost of marketing teams investing funds onto campaigns that me be driven by misleading or inaccurate data.

In order to achieve the end goal of this project, a number of factors should be addressed. These consist of the type of model that should be implemented, what machine learning library should be used, which programming language is preferable for this project, how may the model be trained and what are the options for deployment. For these problems to be address, the project analysis shall be decomposed in to four components: The Machine Learning model, Data preparation, Training and Hosting/Deployment

3.1 The Machine Learning Model

3.1.1 Algorithm

When dealing with image a classification problem such as facial sentiment analysis, there are two machine learning algorithms that deem worthy. Deep Belief Networks (DBN's) were developed as an alternative to back propagation by Geoff Hinton. The idea behind DBN's involves stacking of a Restricted Boltzmann Machines in order to train in a "greedy manner" (Hinton, 2017). This model learns to excerpt hierarchical representations of training data. The second algorithm is convolutional neural networks (CNN's). As explained in the

literature review, a CNN's consist of a number of convolution and sub-sampling layers. It is then followed by a dense ,or otherwise known as, a fully-connected layer. It also uses back-propagation to adjust the weights of the network during training (Gupta et al., 2017).

3.1.2 Programming Language

There are many programming languages that can used for machine learning and artificial intelligence. Brownlee describes the quest for choosing a programming language to be rather difficult, as the choice should be tailored around "your own requirements" and entirely depends on the project being undertaken. However, a opinions on popular machine learning languages are given. Firstly, MATLAB/Octave is described as being "excellent" for dealing with matrices and linear algebra (Brownlee, 2016a). The R language is shown to be a main choice for machine learning as it provides many machine learning algorithms and it is a great choice for developing advanced models. Brownlee states, although it is a good choice, it is seen as having a hard learning curve at first use. Python is said to be competition to MATLAB and R as it's large range of libraries and abilities as widely used in the field of data science (Brownlee, 2016a). An article by Verma sheds light on most popular programming languages in terms job listings for the year of 2016. Coming in first place was Python, as it's popularity is unmatched by any other programming language. Following Python is Java, and after that R is seen to be the third most popular (Verma, 2017). See Figure 3.1 for graphical representation Verma's findings.

In light of the proclamations made above, it is clear that the preferred languages should be easy to learn, are backed by a large community, and is capable of complex mathematical operations. Also, it is desirable that the languages chosen for the proposed language is fast and efficient because of the complex computations that will occur during training.

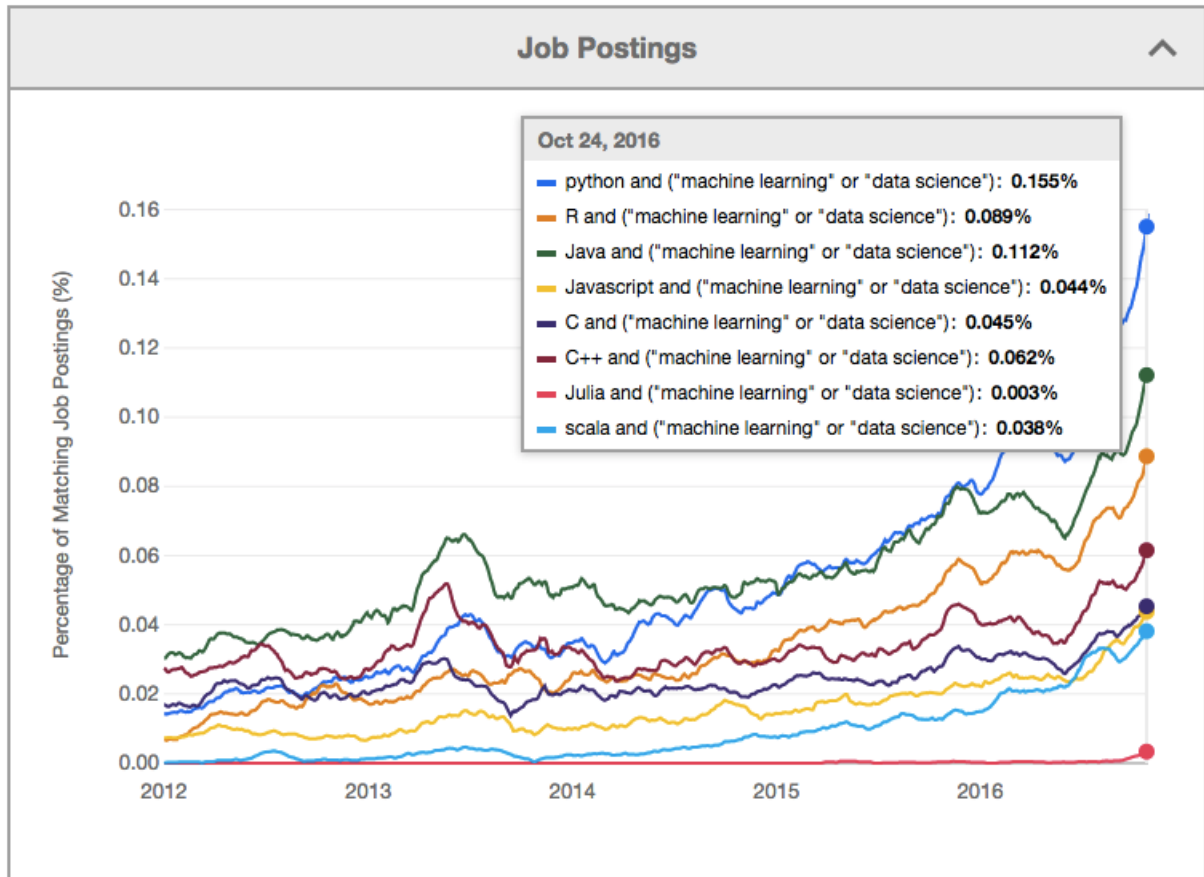


Figure 3.1: Graph of Machine Learning or Data Science Languages for 2016 by Verma (2017)

3.1.3 Machine Learning Library

To speed up the process of implementation, a machine learning (ML) should be used. This will speed up the process of the project as many ML libraries have API's to help eliminate tedious tasks. Also these can be use to reduce the complexity of the length of the program (Jain, 2017). TensorFlow is an open source ML library developed by the Google Brain team. It can be run on CPUs, GPUs and mobile platforms. For machine learning algorithms, such as gradient descent, TensorFlow provides automatic differentiation which can prove to be very advantageous in comparison to other ML libraries. It also supports multiple languages such

as Python, Java and C++ and Go (Jain, 2017). Graph visualisation is also supported. Multi-threading is also achievable with the use of TensorFlow (Jain, 2017). Higher level wrapper libraries such as Keras can use back-end API's such as TensorFlow provide easier implementation with minimalistic coding but also giving the same efficiency and accuracy (Brownlee, 2016b). Scikit Learn is an open source ML library built on top of other libraries such as Matplotlib, SciPy and NumPy. A good feature that Scikit Learn incorporates is the ability of evaluating, chaining and adjusting model hyper parameters (Jain, 2017). Other ML libraries such as Caffe focuses on speed and modularity and is mainly utilized for convolutional neural networks and computer-vision. Another selling point for Caffe is its pre-trained models that do not require any coding or training and it supports GPU and CPU computations. A disadvantage of this library is that it's specifically designed for application implementation, not for research and development (Jain, 2017)

3.2 Dataset

For this project, the machine learning model will require a large image dataset. This dataset will be used to train the model on certain facial feature expressions with supervised learning, therefore a labeled dataset is needed. Acquiring a good dataset is one of the most important parts of the project, as the model only as good as the data you train it with.

3.2.1 Public Datasets

As seen in the literature review, there are many datasets publicly available for use on the Internet that provide labeled data. For example, the CK+ dataset was used by Lopes et al. used labeled data to train their model. The dataset included facial expressions such as sadness, surprise, happiness, anger, fear and disgust. Which is a considerable approach for training the model.

3.2.2 Creating a Dataset

Creating a dataset is another option for training the model. A number of images could be batch downloaded from image search engines such as Bing and Google, and split into training and testing sets. As for labeling, the name of the folder the type of picture is in will serve as the label.

3.3 Training

Training is a vital part of the project and will be the most time consuming. The model will use the chosen data preparation method and use that data as input to the model. There are two ways the model can be trained: Locally and on an Infrastructure as a Service (IaaS).

3.3.1 Training Locally

Training locally involves running code on your own machine to train the model. A main advantage to this is that it is low cost. There are no fees in this approach besides the electricity used by the machine. However, this approach may be harmful to the machine as the high rate of computations produces a lot of heat, which may prove to be detrimental to your hardware. Also, should the machine not have the sufficient hardware, such as a high performing graphical processing unit (GPU), the training elapse time will be significantly larger.

3.3.2 Cloud Training

Training in the cloud involves uploading the model code and dataset to a cloud platform service. These infrastructures provide dedicated hardware for machine learning training such as high performance GPU's and CPU's. They usually provide container environments to run the training. For example, should a model be implemented in Keras or Caffe, the platforms have dedicated runtime environments with these libraries pre-installed. Notable platforms for machine learning training are TensorPort, FloydHub and Amazon's AWS. Although it is

faster to train a model on one of these platforms, they can be expensive, as the free tiers only provide a certain amount of free server usage time.

3.4 Hosting/Deployment

Deployment of the trained model is required to serve it as a web service endpoint. This model should be hosted as an API to enable use from devices besides the machine it was trained on. The API will require a platform that containerizes and supports the machine learning libraries it was used to train with. Additionally, the API should be lightweight and fast for accurate classifications. There are many Platforms as a Service (PaaS) that can be used for this project, notably Heroku, AWS, Azure and Google App Engine all provide a free tier basis for deployment.

3.5 Concluding Objective

In conclusion, this section outlines the objectives for the proposed project sequentially from the initial steps to the end product. The objectives are as follows:

- Acquire a suitable dataset of facial expression images.
- Build a convolutional neural network for facial expression classification using TensorFlow.
- Train the model on a large image data set.
- Save the trained model and deploy it to a Python API.
- Develop a web application that is enabled to record a user's facial expressions
- Use image pre-processing API on the web cam images for more accurate predictions.
- Send snapshots of the users face to the Python API in intervals.

Chapter 4

System Design

The following chapter will briefly explain the chosen design process for the project. The components of the project are broken into four parts: Data Preparation for insight into the data utilized and how it will be prepared, A section on what algorithm and machine learning library will be used, an explanation on the approach for training the model and a Deployment section for the process in which the model was deployed for production. Lastly, the overall system architecture and flow of objectives will be explained.

4.1 Data Preparation

As stated by Lopes, de Aguiar, Souza, and Oliveira-Santos that there is a scarcity of public datasets with for facial expression images, therefore the Cohn-Kanade+ (CK+) dataset shall be used as it provides a wide range of emotions to train the model on. However, in the emotion of disgust and contempt will be omitted from the project as it does not fit the nature of the use case, and they bear too much resemblance to the anger images. Instead, a neutral emotion class will be implemented. The dataset will be preprocessed to reduce dimensionality, and synthetic samples will be generated via data augmentation to increase the size of the dataset and prevent class imbalance. The dataset will then be divided into training and testing sets using split validation.

4.2 Machine Learning Model

For designing the model, the Tensorflow Machine Learning library by Google will be used to design a convolutional neural network. The network consists of several convolution layers, three max pooling layers and a fully-connected layer. The model has six outputs nodes that provide classification for each emotion in the dataset. The model uses supervised learning, with labels for the images it was training on, which will be brought forward in the following section.

4.3 Training

Due to insufficient hardware, the approach of cloud training is needed in order to train the model. The Python code and the dataset are pushed to a containerized TensorFlow environment on the FloydHub cloud platform. The output of the trained model is saved to a Tensorflow *.ckpt* file.

4.4 Deployment

In order to deploy the trained model to production, a Python API was developed using the Flask package, which is a library for running python code on a server. The API is hosted on Heroku PaaS as they provide an easy-to-use and free basic tier service for hosting Python applications. The trained model files are also deployed with the API. These model is read and initialized from the respective files when the API successfully build and deploys. The API accepts 'POST' requests and takes the image as input. The image is then fed into the model and a classification is made, this is then returned to the original sender.

Secondly, a Node.JS web app was developed in order to display how this model can be used in production. The application was also deployed to Heroku. The application uses the

clients web cam in order to record their face. This takes snapshots of the users face and sends the images to the Python API in one second intervals. The application then receives the response from the API and displays it to the screen. See Figure 4.1 for a general design of the user interface for the node application.

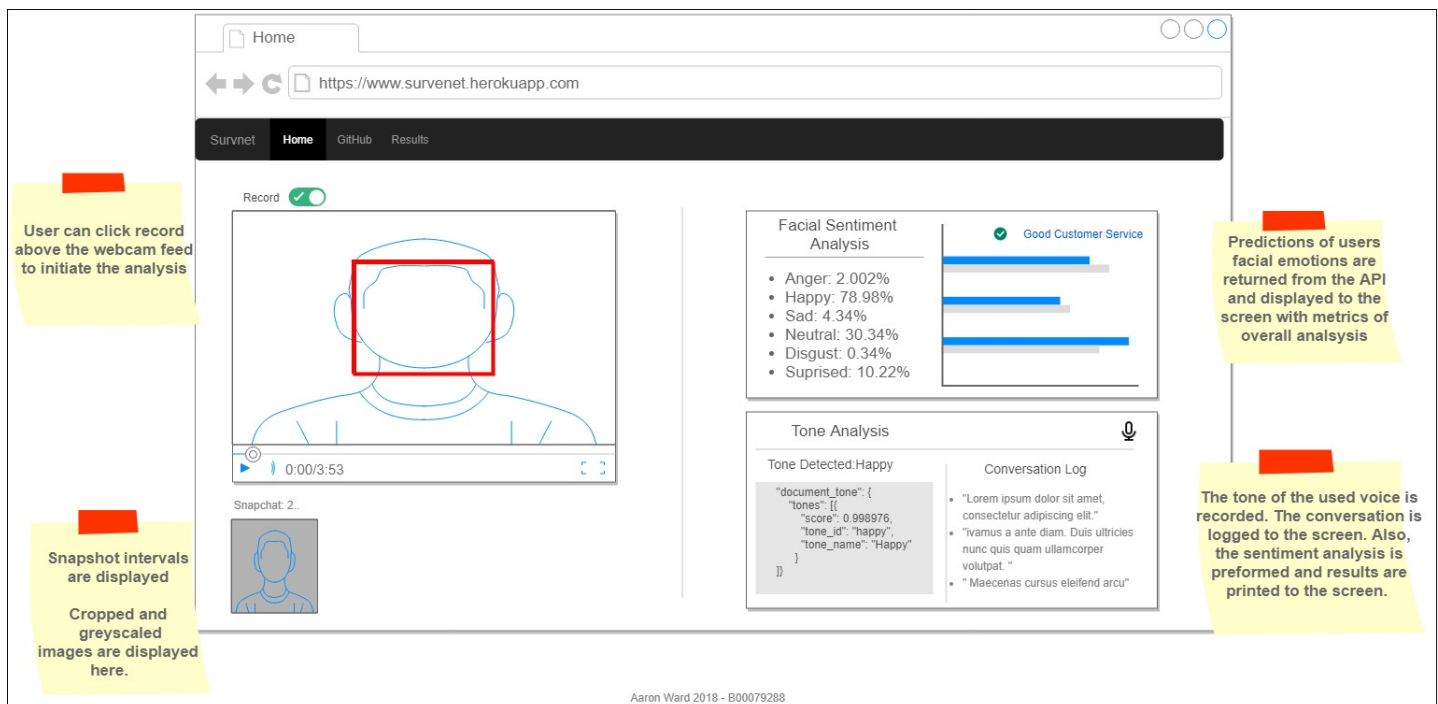


Figure 4.1: User Interface Design For Web Application

4.5 Concluding Remarks of System Architecture Design

In summary, the system architecture will be considered in two parts: Training and deployment. Firstly, the data preparation and neural network scripts shall be written on a local machine. These scripts and dataset will be uploaded to a Tensorflow environment for training on the Flyodhub cloud service. Upon completion of training, the model will be saved and pushed to the *model-serve* GitHub repository that is integrated with the Heroku PaaS. This

repository consists of a Python Flask API to accept POST requests. The Node.js web application shall also be deployed to the Heroku for easy user access. This shall send requests to the model API for classification of images of the user. Please refer to Figure 4.2 to see an illustrated topology of the system.

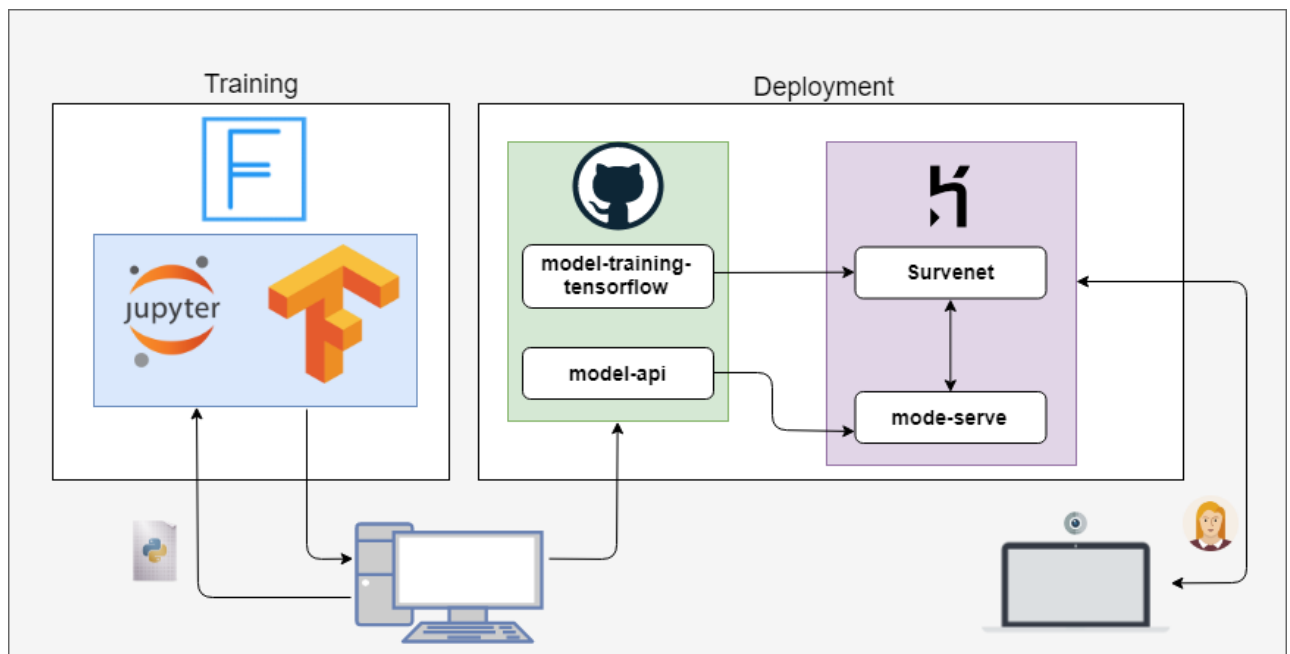


Figure 4.2: System Architecture of Training and Deployment

Chapter 5

Implementation

The following chapter will outline the implementation process and how the project was developed. Firstly, an overview of the dataset used shall be given with information on how the images were preprocessed and augmented for training. A section for the model implementation will be given to describe how the convolutional neural network (CNN) was developed using Tensorflow. This is followed by the deployment process of the Tensorflow Python API. Lastly, the steps in which the Node.JS web application was made shall be touched upon, accompanied by the design and features choices.

5.1 Data Understanding

As stated in the system design, the dataset that will be used is the Cohn-Kanade+ image dataset, which release in 2000 with the purpose of classifying facial expressions (Lucey et al., 2010). The dataset consists of images of 210 subject between the ages of 18 and 50. Each subject is asked to show a a facial expression, beginning with a neutral facial expression that eventually lapses to the target emotion. The digital images come in either a 640x490 or 640x480 pixel format. Furthermore, the images either consists of an 8-bit grayscale or 24-bit colour format (Lucey et al., 2010). The dataset is made up of 593 image sequences and provides labels for each sequence, ranging between 0 and 6. Refer to Figure 5.1 for a summarized illustration of how these sequences are built.



Figure 5.1: Image Sequence From Neutral to Happy

It should be noted that the figure above is not a full image sequence and the some transitional images have been omitted. Moreover, it should also be known that there are inconsistencies in the dataset, such as a number subject not having image sequences for each certain emotions and label data missing for some images. This is acknowledged in the *README* file created by Lucey et al. that is contained within the dataset, where it is declared *"IF THERE IS NO FILE IT MEANS THAT THERE IS NO EMOTION LABEL (sorry to be explicit but this will avoid confusion)"*.

5.2 Data Preparation and Preprocessing

A number of preprocessing steps were taken in order to prepare the images for training the network. These steps were required to ensure maximum possible accuracy and minimal training time as the nature of working with neural networks can be computationally expensive when accompanied with large files such as images. The steps are as follows: Image extraction, Gray scaling, Facial Cropping, Data Augmentation and Data Splitting.

5.2.1 Image Extraction

Due to the structure of the image sequence within the datasets, it is undesirable to used all images within each sequence as that do accurately resemble the facial expression it is

used to represent. Therefore, for each sequence the last four images were extracted from their directory and relocated to a new directory under the category of facial expression they represent. As stated in the system design, images for disgust and contempt are omitted from this new dataset. Furthermore, because there is now class for a neutral facial expression, the first four images from a sequence in each subject was extracted.

5.2.2 Gray Scaling

The CK+ dataset consist of a majority of gray images. However, the extended version of this dataset contains some images sequences with coloured images. When working neural networks, it is significantly more computationally expensive to process a coloured image over a gray one due to the number of colour channels. To mitigate this, a Python script was created to traverse through each image of the newly extracted dataset to convert all images to grayscale using the PILLOW library.

```
from PIL import Image
import numpy as np
import os, os.path
img_path = '<DATASET_DIRECTORY>'

def grayify(file_name):
    image = Image.open(img_path + file_name)
    image = image.convert('L')
    image.save(img_path + file_name)

#Load the directory and traverse over all the image files
list = os.listdir(img_path)
for file in list:
    file_n = file
    print(file_n)
```

5.2.3 Facial Cropping

Following the gray scaling of all images, dimensionality reduction was implemented on the images. This was done by cropping each image down to only the facial surface area. This is done to reduce the noise of the data and to remove any features in the backgrounds that may be learned by the network that do not represent the facial expression. To do this, a Python script was written that reads in all the images from the dataset and crop the region of the image that contains the subject faces. This was done using the OpenCV library.

```
def facecrop(image):  
    face_cascade = cv2.CascadeClassifier  
    ('haarcascade_frontalface_default.xml')  
  
    img = cv2.imread(image)  
    minisize = (img.shape[1],img.shape[0])  
    miniframe = cv2.resize(img, minisize)  
    faces = face_cascade.detectMultiScale(miniframe)  
  
    for f in faces:  
        x, y, w, h = [ v for v in f ]  
        cv2.rectangle(img, (x,y), (x+w,y+h),  
            (255,255,255))  
        sub_face = img[y:y+h, x:x+w]  
        fname, ext = os.path.splitext(image)  
        cv2.imwrite(fname+"_cropped_"+ext, sub_face)  
  
    return  
  
list = os.listdir(<DIRECTORY_NAME>)  
for file in list:  
    facecrop(<DIRECTORY_NAME> + '/' + file)
```


This was done for all images, however, some images were not correctly cropped due to noise in the image causing it to misclassify the facial region. Some examples of this might be only half the face being cropped into the new image or just the subjects shoulder being visible. These worthless images were manually deleted after the newly cropped images were evaluated. Please refer to Figure 5.2 for example of the facial cropping.

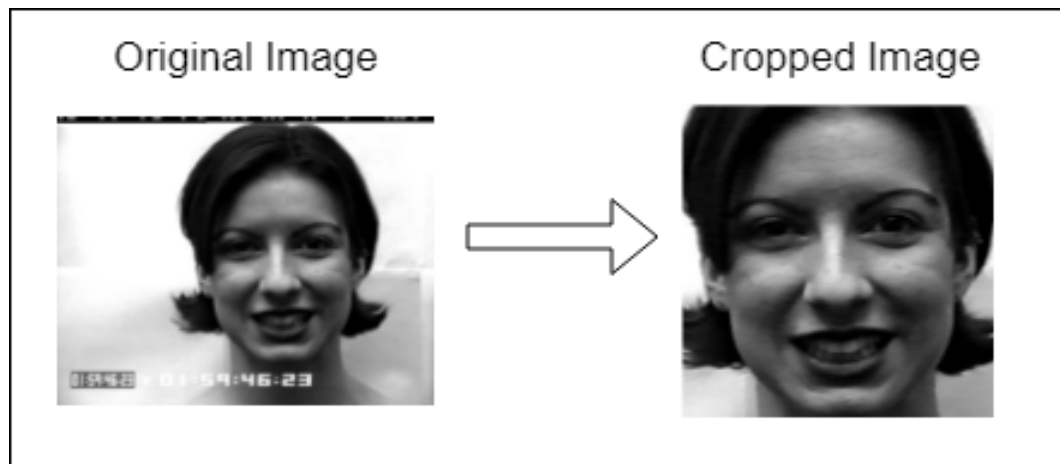


Figure 5.2: Image Cropping on Facial Regions

Facial Expression	Cardinality
Anger	601
Fear	427
Happy	883
Neutral	668
Sad	641
Surprise	639
Total	3879

Table 5.1: Initial Image Count

5.2.4 Image Increasing Through Data Augmentation

Upon inspection of the dataset, in regards to the number of images for certain facial expressions, it was noted that there was an insufficient amount of images to train the network. This can be seen in table 5.1.

The initial step to increase the size of the data set was to flipped versions of all the images. Not only does this double the size of the dataset, but helps the network to better handle facial variance when dealing with new unseen data. Also, it will decrease the chance of under-fitting while training the model. Following this step, a check was done on the class balance. Using the Matplotlib Python library, the balance of each class was plotted by counting each image in accordance to it's respective label, as seen in Figure 5.3

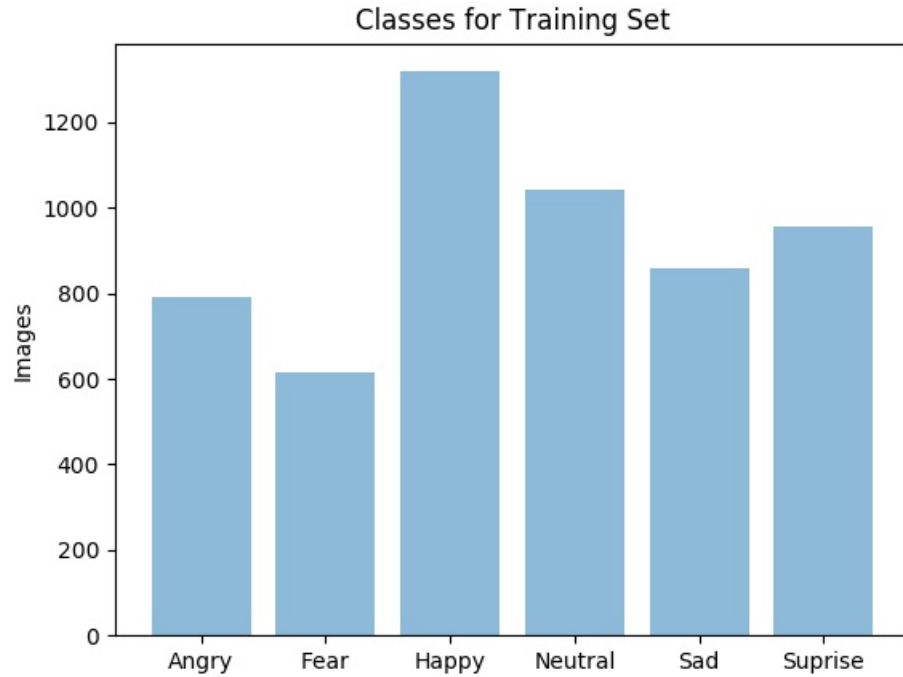


Figure 5.3: Class Imbalance

As seen above, expression 'Anger' and 'Fear' are under represented while 'Happy' is overly represented, relative to the rest of the dataset. How this problem was addressed was to create synthetic sample images from the existing ones by the means of skewing and augmenting the images. This can be seen in Figure 5.4, where the top row displays the original cropped images. Beneath, are the slightly skewing images. This was implemented using a Python library called Augmentor, which allows you to specify the directory and number of altered samples you would like, and it randomly picks images within the directory, creating an entirely new back of images that have been stretched to a degree.

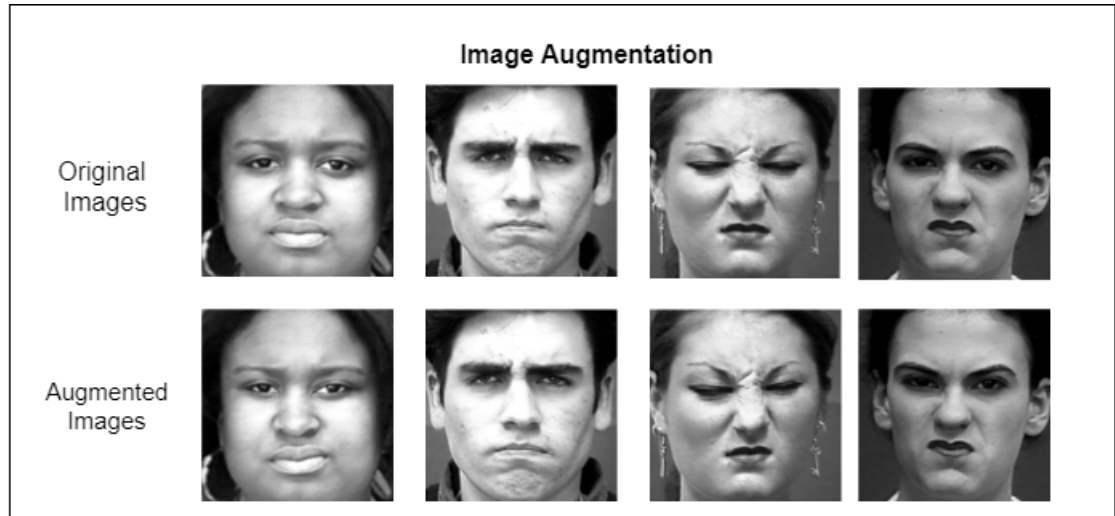


Figure 5.4: Example of Augmented Images

This was done for all classes to increase the number of samples in the dataset, until a number of 1750 images are present for each class. This amounts to a total number of 10500 images in total across the entire dataset. The class balance can be seen in the bar chart illustration in Figure 5.5, which has been plotted using the Matplotlib library. In conclusion, an additional 6,621 images have been created from the original dataset.



Figure 5.5: Class Balance

5.2.5 Data Splitting

The last step in the the preparation phase was to apply split validation to the dataset. The dataset was split into training and testings sets at a divide of 80/20 - meaning 80% of the dataset will be used for training (1400 images per class) and 20% will be used for testing the model (350 images per class). Please see the Python code below showing how this was achieved.

```
import os, os.path
import math
from PIL import Image

old_path = 'C:/Users/aaron/Desktop/Cropped_Dataset/happy/'
```

```
new_train_path = 'C:/Users/aaron/Desktop/data/training/happy/'
new_test_path = 'C:/Users/aaron/Desktop/data/testing/happy/'

#Load the directory and traverse over all the image files
list = os.listdir(old_path)

# define the size of the first 80 percent of images
num_files = len(list)
num_training_files = num_files * .8
num_training_files = math.ceil(num_training_files)

num_testing_file = num_files * .2
num_testing_file = math.ceil(num_testing_file)

#Add the first 80 percent to the training folder
for img in list[1:num_training_files]:
    i = Image.open(old_path + img)
    i.save(new_train_path+img)

#Add the remaining 20 percent to the training folder
for img in list[num_training_files:]:
    i = Image.open(old_path + img)
    i.save(new_test_path+img)
```

5.3 Implementing the Machine Learning Model

When implementing the machine learning model with Tensorflow, the initial step used is to import all the libraries that deemed necessary for preprocessing and training. These include

Tensorflow, Numpy, Skimage, PIL etc. Secondly, the image data was import with it's respective labels. A list is used to store the image RGB data for every image in the dataset. Secondly, for each image in a directory under a certain class, a label of that class is added to the labels list. Refer code below to see how this was implemented.

```
def load_data(TRAINING_DIR):  
    images = []  
    labels = []  
  
    directories = [d for d in os.listdir(TRAINING_DIR)  
    if os.path.isdir(os.path.join(TRAINING_DIR, d))]  
  
    # Traverse through each directory and make a list  
    # of files names if they end in the PNG format  
    for d in directories:  
        label_directory = os.path.join(TRAINING_DIR, d)  
        file_names = [os.path.join(label_directory, f)  
        for f in os.listdir(label_directory)  
        if f.endswith(".png")]  
  
        #Traverse through each file , add the image data  
        # and label to the 2 lists  
        for f in file_names:  
            images.append(skimage.data.imread(f))  
            labels.append(int(d))  
    return images, labels  
  
images, labels = load_data(TRAINING_DIR)
```

Following this, shuffling of the data is performed, this is done to prevent overfitting of the model. Then further preprocessing steps are taken. In this case, each image in the list of images are sub sampled from their original sizes down to a 50x50 pixel size. This was done

with the Skimage library to reduce the dimensionality of the images for the network to better handle the input data. The list images were traversed and resized using the tranform function.

```
images = [transform.resize(image,(50, 50))  
          for image in images]
```

After basic data imports, defining the computation graph for Tensorflow is required. Tensorflow placeholder were then declared for later use when tensors need to be fed to the TensorFlow session, along with another few initial variables such as number of epochs, the batch size, dropout rate etc. When all the main variables needed for TensorFlow are made, the structure of the network was mad. This was done using the tf.slim library, which a TensorFlow package that allows you to define layers in a network easily.

In total there are 10 convolution layers with 5 MaxPooling layers. The convolution layer is used to extract features within the image while pooling reduces the dimensionality of the feature maps, but retains majority of the useful data. Lastly, a fully connected layer is de-

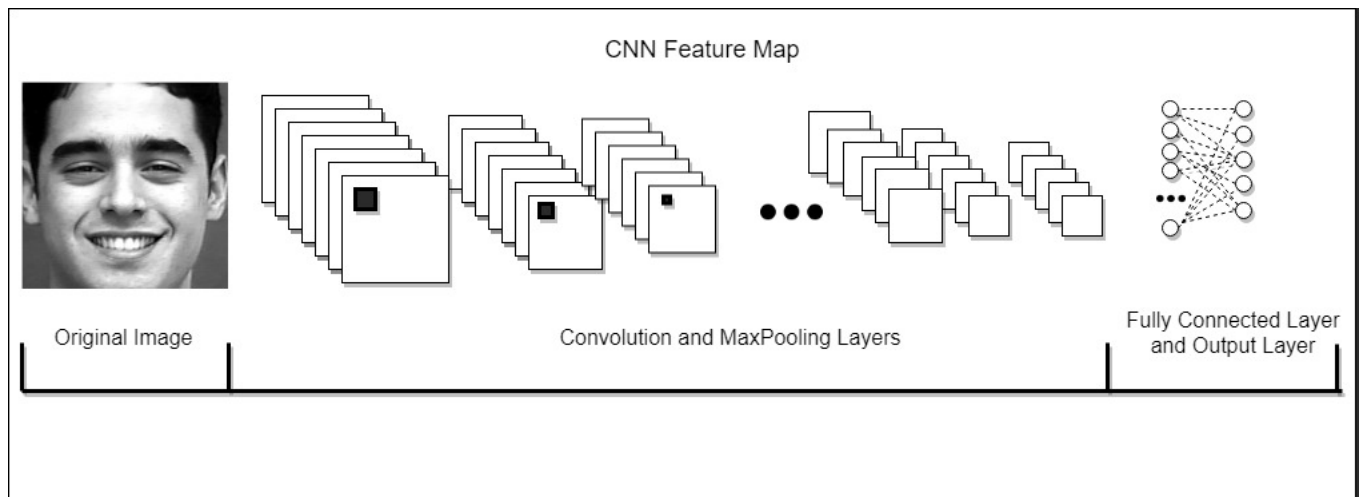


Figure 5.6: Feature Map of CNN

fined, which will be used to produce a predicted output. The reason dropout is used in this case is to reduce the chances of over fitting the network. After each training iteration (epoch),

only 80 percent of the trained neurons are kept.

```
net = slim.conv2d(net, 32, 3)
net = slim.conv2d(net, 64, 3)
net = slim.conv2d(net, 64, 3)
net = slim.max_pool2d(net, 3, stride = 1 )
net = slim.conv2d(net, 96, 3)
net = slim.conv2d(net, 96, 3)
net = slim.max_pool2d( net, 2, stride = 2)

net = slim.conv2d(net, 128, 3)
net = slim.conv2d(net, 128, 3)
net = slim.max_pool2d( net, 2, stride = 2)

net = slim.conv2d(net, 128, 3)
net = slim.conv2d(net, 128, 3)
net = slim.max_pool2d(net, 2, stride = 2)

net = slim.conv2d(net, 128, 3)
net = slim.max_pool2d(net, 2, stride = 1)

net = slim.dropout(net, keep_prob = keep_rate
                    , is_training = is_training )
```

Following the structure set up of the network, a function is defined that runs the Tensorflow session, which takes the `x` placeholder as a parameter. Within this function we define the loss function used within the network which is softmax with cross entropy. Also the Adam optimizer is used for back propagating through the network and adjusting the weights. A

learning rate of 0.002 was chosen for the final implementation after showing in experimentation that this reduced the loss the most.

```
loss = tf.reduce_mean(tf.nn.softmax_cross_entropy_with_logits
    (labels = y, logits = output))
total_losses = tf.losses.get_total_loss
    ( add_regularization_losses=True ) + loss

update_ops = tf.get_collection(tf.GraphKeys.UPDATE_OPS)
with tf.control_dependencies(update_ops):
train_op = tf.train.AdamOptimizer( learning_rate=0.002 )
    .minimize( total_losses )
```

When the session is ran, the TensorFlow variables are initialized and the training begins. The list of images and labels are segmented into batches of size 100 to prevent an OOM error, as loading all the images into memory can cause an overflow. The images and labels are fed into the TensorFlow runtime environment for training. After each epoch, the accumulated loss and batch accuracy is calculated and printed to the screen. After the network have been trained for the specified number of epochs, it evaluated the accuracy on the test data and a TensorFlow *.CKPT* model file is saved to disk.

5.4 Deploying the Trained Model

/*****/

5.5 Implementing the Node.JS Application

To develop a web application for the user to interact with, Node.JS was used to implement a simple one page application that accesses the users webcam. Firstly, a javascript webserver was created using the Express npm module, which provides functions for routing and serving

html pages. A port is initially set using either port 5000 for local development, or a randomly allocated port for deployment.

```
app.set('port', (process.env.PORT || 5000))
```

This is followed by providing the home page when the base route is called by from the client. When the '/' route is called, a html page containing the application is delivered to the users browser and displayed in the DOM.

```
app.get('/', function (req, res) {  
  res.sendFile(path.join(__dirname, '/index.html'));  
});  
  
var server = app.listen(app.get('port'), function () {  
  var host = server.address().address  
  console.log('Application running on port', app.get('port'))  
})
```

5.5.1 Facial Tracking With a Users Webcam

The user interface design of the application is very simple. On the left hand side a the page the webcam feed is displayed. This accesses the user's machine's webcam and displays it to the screen using the html **canvas** element. Canvas is a container for drawing graphics to the page. For facial tracking, a library called Tracking.js was imported. Trackin.js is an open source library created by Eduardo Lundgren for object, colour and face detection using javascript. The reason for this library choice was because other alternatives, such as OpenCV, deemed to be very heavy weight in comparison and API services that have also been considered such as cloudinary would reduce classification speed as it would be computationally expressive to make multiple requests for facial cropping while using the application. In light of this, tracking.js provides a lightweight and quick solution for detecting faces. Using what is known as haar cascades, object classification and detection is made simplified and provides

fast calculation speeds. In terms of the web application, the canvas drawing of the webcam feed is read and interpreted by tracking.js and the facial features are detected. A yellow box is drawn around the detected facial area.

```
var tracker = new tracking.ObjectTracker('face');
tracker.setInitialScale(4);
tracker.setStepSize(.5);
tracker.setEdgesDensity(0.1);
tracking.track('#video', tracker, { camera: true });
tracker.on('track', function(event) {
  context.clearRect(0, 0, canvas.width, canvas.height);
```

One function that tracking.js does not provide is the ability to crop the detected area of the stream. To get around this, java script code was developed to mark the area in which the square was being drawn around the users face. In each frame of a users face being detected a new square is drawn to the canvas, so every time that a new square is displayed to the screen, this marks the new coordinates of the area in which is needed for cropping.

```
rect_width = rect.width; //
rect_height = rect.height;
rectX = rect.x;
rectY = rect.y;

...

ctx.drawImage(video, rectX+ 100, rectY +90,
               rect_width +70, rect_height +50, 0, 0, 300, 150);
```

After it is known where the users face is positioned in the shot, the cropped area is displayed in a separate 100x100 pixel canvas area, named ctx, below the feed. To ensure that the trained Tensorflow API does not become overflowed with image data, an interval timing is implemented. This involves setting a timer as to when an image is cropped because it

would be disadvantageous and computationally expensive to have every frame to be sent to the API. In this case, the interval is set to 1 second. To initiate a session with the model and begin the facial sentiment analysis, a button was added to the UI which begins the analysis. Please refer to the Figure 5.7 for a screenshot of the facial tracking in action.

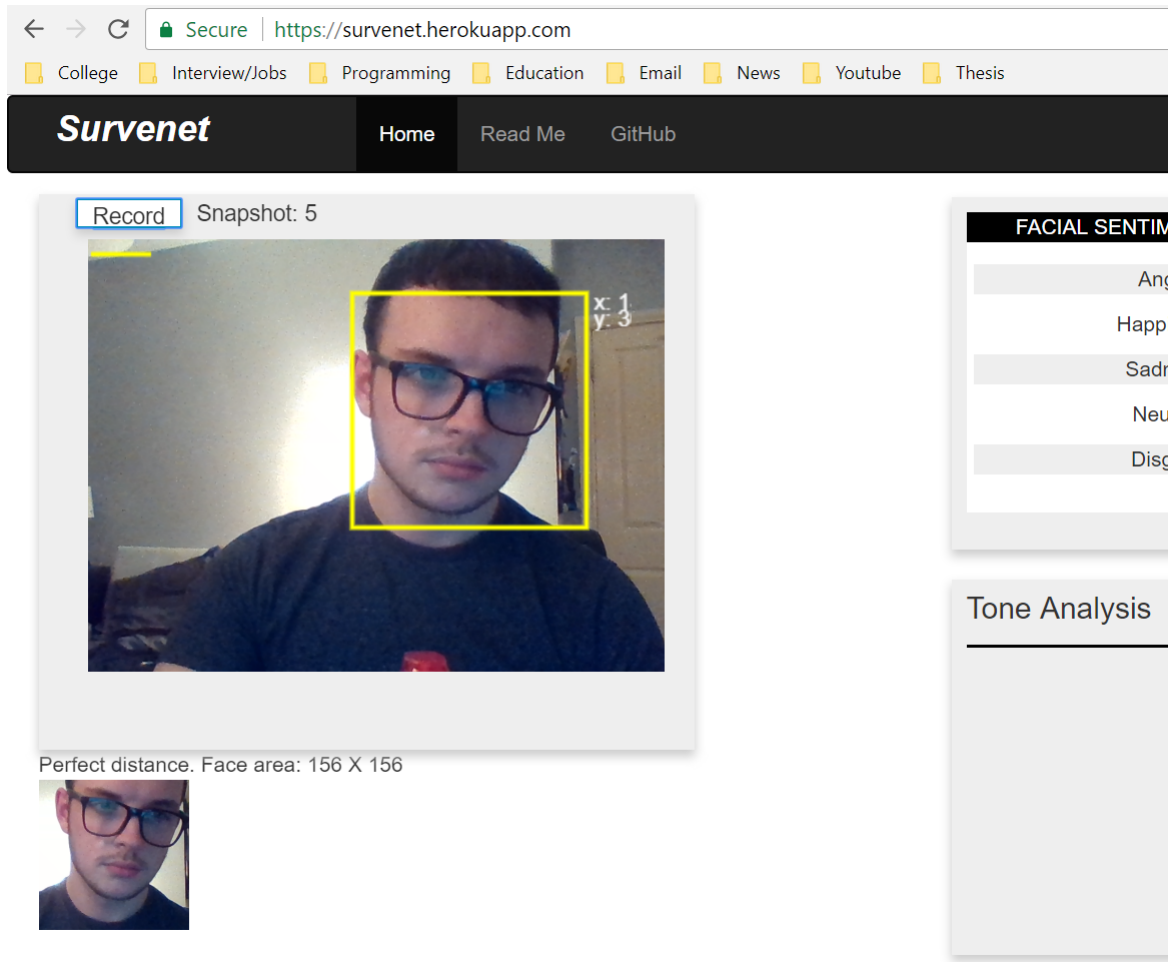


Figure 5.7: Webcam Feed with Facial Tracking and Cropping

5.6 Deploying the Node.JS Application

For deploying the web application, the Heroku PaaS of service was used. Using GitHub integrations, whenever a new version of the application was pushed to the remote repository a new build was commenced. If the build was successful, the application would be live for use at <https://survenet.herokuapp.com>.

5.7 Concluding Remarks of Implementation

In summary, many data preprocessing steps were taken to ensure the best possible result of the model. These include gray scaling, facial cropping, data increase by creating flipped copies and image augmentation. These steps were taken to ensure the best possible results when evaluating the model. Secondly, the data was split into training and testing sets. A fully working TensorFlow model was created in python and trained on the FloydHub could training platform. A facial tracking web application was built for recording the used face and deployed to the heroku PaaS.

Chapter 6

Testing and Evaluation

The following chapter will cover the steps taken for evaluating the model in terms of performance and accuracy. A number of performance measures are used for determining how well the model handles data that it has not been trained with. These include training evaluation, testing with the testing data and inference with new data.

6.1 Training Evaluation

During the training of the model, a number of metrics were recorded for evaluation. The loss (often referred to as the cost function) is calculated by measuring the difference of the actual label value minues predicted output (See below).

$$H_y(y) := - \sum_i y_i \log(y_i)$$

This value can be seen as a measure of how well the model is training. The closer the loss is to zero, the more accurate the model is at classifying. As seen in Figure 6.1, the initially loss for the first epoch was approximately 185. This value decreased gradually throughout the training of the network, getting closer to 0.

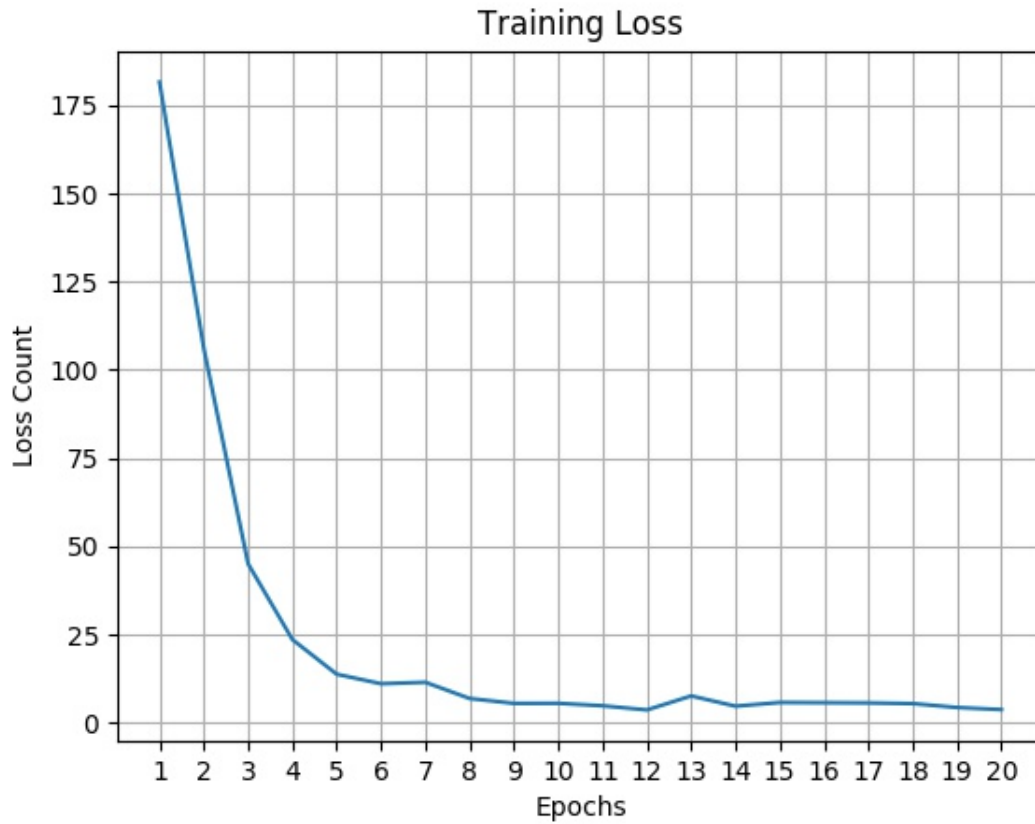


Figure 6.1: Loss Function Values

The second training measurement taken into account was the accuracy throughout each step in training. This is measure by the adding the true positive with the true negative results, and dividing the sum by the total number of samples (See equation 6.1.1). It is said that using accuracy is not a desirable method of measuring performance, as it can give misleading results if there is a high class imbalance, which is not problem in our case as it was made sure that each class was represented equally.

$$Accuracy = \frac{Truepositive + Truenegative}{Totalpopulation} \quad (6.1.1)$$

Intuitively, it is desired to have the highest accuracy possible. As can be seen in Figure

6.2, the model performed rather well as it reached a high accuracy of approximately 98 percent and plateaued for the remainder of training.

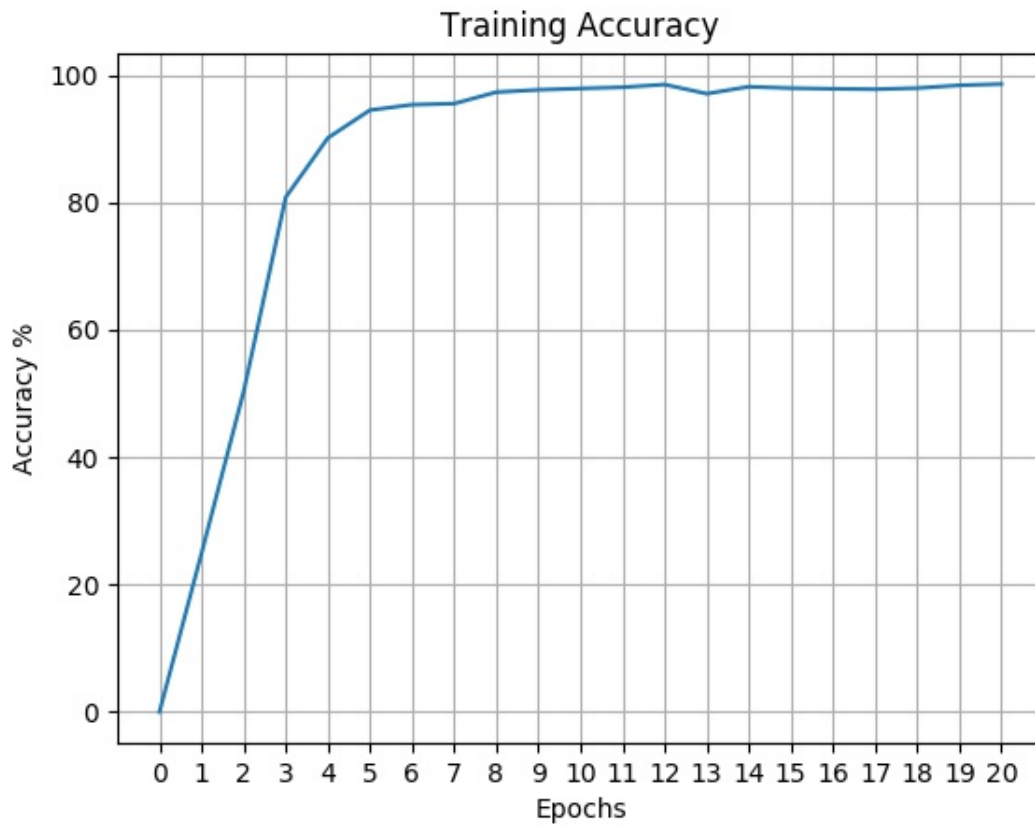


Figure 6.2: Accuracy Values

6.2 Testing Model with Testing Data

As stated in the implementation chapter, the dataset was split into training and testing sets. out of the 1750 images for each class, 1400 of them were used for training, and the remaining 350 were used for testing the models performance. A python evaluation script was used for loading each set of classes individually and feed them to the trained model. Upon inspection, the network performs very well with most of the images being classified correctly, apart from the neutral class, which can be seen in Figure 6.3.

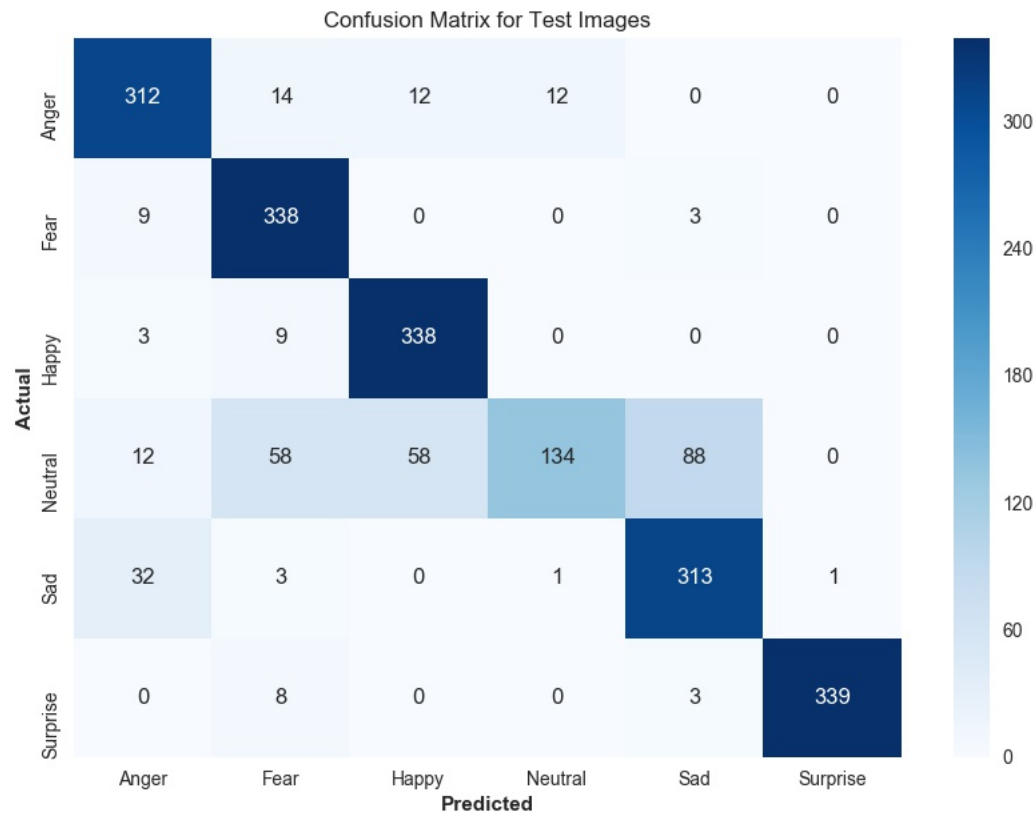


Figure 6.3: Confusion Matrix Heatmap

From this confusion matrix we are able to plot out a number of performance metrics besides the basic training accuracy and loss. Firstly, the recall of each is measured. The recall of a class can be described as the number of true positives divided by the number of true positives and false negatives, as seen in equation 6.2.1.

$$Recall = \frac{Truepositive}{TruePositive + FalseNegative} \quad (6.2.1)$$

Also, the precision of model can be calculated. The precision is a measure of the the number of true positives classified divided by the sum of true positives and false positives, which can be seen in equation 6.2.2

$$Precision = \frac{Truepositive}{TruePositive + FalsePositive} \quad (6.2.2)$$

From these equations, and using the results found in the confusion matrix, the table below displays the performance of the model. See Table 6.1 for further insight into the results.

Testing Performance Measures		
Class	Precision	Recall
Anger	84.7%	89.14%
Fear	78.6%	96.5%
Happy	82.8%	96.5%
Neutral	91.15%	38.2%
Sadness	76.9%	89.4%
Surprise	99.7 %	96.8%
Accuracy	84.47%	
Average Precision	85.64%	
Average Recall	84.42%	

Table 6.1: Table of Performance Measure Results

6.3 Testing Model with New Data

Single inference was performed with images taken from google so see how well the model performed without any of the preprocessing steps. One image was chosen at random for each emotion. From the results seen in Figure 6.4.

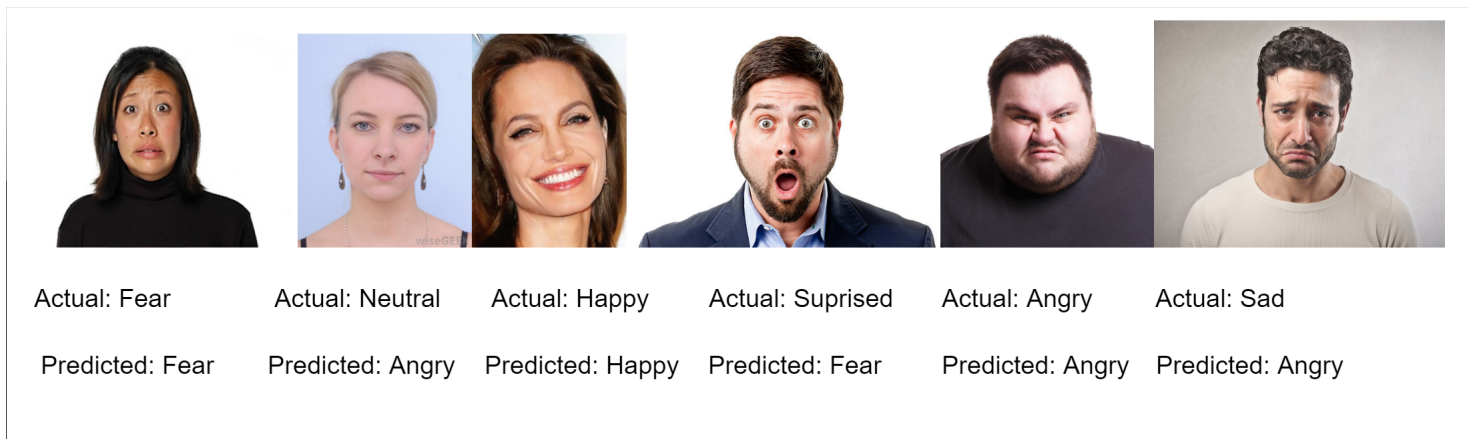


Figure 6.4: Single Predictions on Non-preprocessed Images

6.4 Concluding Remarks of Testing and Evaluation

In conclusion, the training performance evaluation was discussed in regards to the loss and accuracy of the model during the training stage. Testing was done on the trained model with 350 images per class with a highly correct classification score excluding the neutral class. Recall and precision scores were calculated using the a confusion matrix. Lastly, single inference was performed using randomly selected images sourced from Google images in order to examine how the model performed.

The neutral class did not have as high of an accurate classification score as the rest of the classes. A speculated reason for this might be because the facial features of the subject may just naturally appear like other facial features, such as sadness, which was classified 88 times out of 350. Also, it is possible that by the augmented images for this class may have

morphed too much, therefore making them appear to look like another class (happy or sad in this case). In terms of the single predictions performed, Although these classifications were only moderately accurate (classifying 3/6 images correctly), it should be noted that facial cropping needs to be performed on each image for more accurate results.

Chapter 7

Results and Discussion

7.0.1 Model Accuracy

7.0.2 Usability

7.1 Discussion

Chapter 8

Conclusion and Further Work

8.1 Conclusion

8.1.1 Further Work

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Appendices

Appendix A **Code Snippets**

Appendix B **Screen shots**