**CHEZER - CHILD EMOTION ANALYZER**

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Specializing in Data science.

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Dissertation submitted in partial fulfillment of the requirements for the Bachelor of Science in Information Technology Specializing in Data science.

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# DECLARATION

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Signature of the Co-Supervisor: Ms. Madhuka Nadeeshani Date:

ABSTRACT

With the advancement of technology in the field of health and education, the interpretation of human facial emotion expressions gain utmost prominence where a necessity of automated systems for better analysis is urged. On such aspect, the field of computer vision and human computer interaction has been evolved with various automated systems. Even though various studies on facial emotion expressions exist to date, the ability to analyze fine grained aspects such as the intensity and level of emotion is yet an unseen scope. Additionally, the misconception of assuming children and adults to show similar patterns in their facial expressions do still exist even though there are clinically proven evidence of human emotions being gradually developed with age. Thereby the state of art of this component comprises of three novel findings such as the identification of facial action unit stimulation in child emotions, automating the child emotion and emotion level prediction using the action unit stimulations identified and improvise the results considering the age group of children. The action unit stimulation was analyzed using a statistical technique known as Exploratory factor analysis which showed a consistent result with FACS. Through the AU stimulations identified, it is observed that a child video can be predicted for the emotion and emotion level with an accuracy of 86% through a Random Forest classifier while the age wise emotion level analysis revealed an accuracy within the range of 84-89%. Happy and surprise emotion level predictions yielded better results over sad and disgust emotion levels whereas an age wise analysis improvised the automated system created further aiding immense contribution for child clinical assessments.

***Keywords*** *– Action unit, Exploratory factor analysis, Machine learning, Child Emotion level.*

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# LIST OF ABBREVIATIONS

|  |  |
| --- | --- |
| **Abbreviation** | **Description** |
| FACS | Facial Action Coding System. |
| FAU | Facial Action units. |
| EFA | Exploratory Factor Analysis |
| PCA | Principal Component Analysis |
| FER | Facial Emotion Recognition |
| FEE | Facial Emotion Expression |
| HCI | Human computer interaction |
| CNN | Convolutional Neural Network |
| AI | Artificial Intelligence |
| SVM | Support Vector Machine |
| ASD | Autism Spectrum Disorder |
| ML | Machine Learning |
| RF | Random forest |
| KNN | K Nearest neighbor |

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# 

# INTRODUCTION

## Background

Facial expression is known as the change in the appearance of face due to movement of facial muscles that occurs as a response to a stimulus. Understanding emotions and facial expressions gain utmost prominence in the field of clinical practices and education thereby aiding in prior identification of various clinical and psychological factors of human growth and development. While emotions can be conveyed in various ways, such as speech signals and other bodily gestures, recognizing emotions of individuals through diverse facial articulations is an attention-grabbing problem due to the complexity of facial features and the presence of diverse factors influencing them with growth. On the other hand, the signals transmitted and received nonverbally do deliver more subtle information which helps understanding the state of mental health more precisely. It is highly evident that facial emotion analysis has been showing significant progress in areas such as depression analysis in mentally unfit people specially students, crime detection, treating psychologically affected patients, analyzing interviewee’s state of mind, and even assessing children with disorders such as autism spectrum disorder (ASD).

Overall, the need to identify facial emotions precisely has gained attention due to various factors influencing it such as the age, gender, and the environment in which a person lives. Studies [1] and [2] detail that the appearance of facial emotions vary with age and gender mainly due to biological causes, cultural expectations and even the life experiences throughout one’s growth and development. Study [3] states that even though emotion expressions develop between infancy and adulthood the emotion trajectory is seemed to be understood across a wide age-range rather than focusing on specific age groups. An understanding on the impact caused by the factors such as age groups and genders would aid in providing individual attention thereby supporting the identification of human mental growth and development in depth. Even though studies reveal the various factors influencing emotions, research on facial emotions with concern to those factors are surprisingly sparse.

Emphasizing further on the influence of age in emotion analysis, identification of child emotions gain prominence. The reason behind this is that human undergo a rapid socio emotional growth within their childhood and in such aspect, more concern should be provided to ensure that the child attains the milestones relevant to their age on time and concerns on the raise of symptoms related to developmental disorders should gain immediate attention to prevent serious malfunctions and disorders. Prior identification of any malfunctions could lead to early intervention thereby preventing harmful conditions during childhood itself. Even though previous works [4] and [5] that considered on factors influencing child emotions exist and assessed on child sensitivity, it was all done by manual surveys which was task based and wasn’t a real time emotion identification. So, a system to track the child emotions considering their age groups on their day-to-day development seems to be a very important innovation needed in the health care and education sector which has a close relationship with growing children.

According to the guideline on child development and developmental screening for primary health care workers provided by the ministry of health and indigenous medical services [6], there exist developmental milestones which the child has to attend within a specific age group. It is detailed as even though children tend to have the ability to develop their emotional, social, and cognitive skills by exploring the environment and identifying the stimuli they receive, the failure of children in doing so needs to be assessed in a timely manner so that the process can be optimized by parents and caretakers at the right time thereby providing a developmentally conducive atmosphere to the children. Accordingly, assessing these behaviors could be highly challenging as the child facial emotions are very mild and subtle thus varying rapidly with time. Also failing to understand children in their natural environment can cause the child to be anxious resulting in misconceptions. Thereby a need to assess child emotions while they exist in their natural environment is necessary aiding to an unbiased child growth and developmental assessment.

Emphasizing further on the fact, that children tend to show very mild and delicate emotion expressions, identifying the fine-grained minute changes prominently seems to be crucial. On such context, there exist various underlying factors which helps us identify the micro expressions and real time facial emotions seen in children precisely. Emotion intensity is one such important factor among them. In [7], emotion intensity is defined as the variations in magnitude of emotional responses where the literature also states that not everyone could express their emotions in a similar manner. Variation of the intensities in emotions can be vaguely understood by human even though there is no systematic representation of it in the domain of human computer interaction to date. Literature [8] provides a detailed analysis on the sensitivity of children for the varying intensity of emotions stating the methodologies followed to assess how children recognize different intensity of emotions which are way more diverse than the intensity of expressions seen in the day to day activities and proposes the necessity to analyze the emotion intensities that can be expressed by children. In a previous work such as [9], Paul Ekman and Wallace V. Friesen, the pioneer in the field of facial emotion recognition were successful in categorizing the facial emotions into six main categories as happy, sad, anger, surprise, disgust, and fear where it led to the creation of numerous facial emotion recognition (FER) systems that could predict the emotion expressed. Yet, this emotion categorization doesn’t reveal the other important traits of emotions such as the intensity / level of emotion and the valence of it.

The emotion intensity is one of the main attributes that is useful in identifying even the subtle changes in the emotions occurring within an individual [10]. Assessing the intensity of emotions expressed by an individual is a common task that could be done by human easily which is referred to as emotion level. While assessing the intensity, it is convenient to understand it along with the emotion in an ordinal manner representing a certain hierarchy that facilitates comparison between individuals. Thereby there was a question if Artificial intelligence (AI) could achieve this characteristic similar to human!

While focusing on the automated systems created so far and their contribution on child development, the aforementioned factors seem to be lacking causing a lot of difficulties to the individuals of this domain in making a genuine contribution to improve child mental well being. Even though numerous attempts with regard to this are taken in the field of computer vision and human computer interaction a unified system addressing all of them are yet not available. As discussed, the aim of this research is to reveal several factors that might explain the age-related differences in emotion level identification and thereby provide a user-friendly gaming mobile application. The application is designed in such a way that real time videos of children playing a game are fed as input to obtain the accurate emotion levels expressed in a man heuristic manner considering three main levels of emotions such as high, moderate, and low which is also specific to the child age groups along with more details of the facial muscle growth in children providing insights on understanding children with risk of mental disorders aiding earlier interventions and therapies.

## Literature Survey

Even though there exist various articulations through which the emotions can be understood, facial expressions and its perception is a long time emphasize in the research areas. Face is defined to be the most expressive part of human as a lot of nonverbal information can be conveyed via various parts of the face such as the eyes, lips, eyebrow movements etc. The rapid change seen in such features such as the dilation and constriction of eyes, raised and lowered eyebrows, dropped or raised corners of mouth etc. are the key factors which leads human to identify and variate emotion and the emotion levels at a glance. Thereby the incorporation of emotional intelligence to automated systems can be enhanced if the systems had the ability to understand these subtle changes distinctly. Thereby the driving concept of the automated system created in this research is the facial action unit (FAU) which is presented by a human observer-based system known as the Facial action coding system (FACS) [11] which is constructed to identify the subtle changes occurring in facial features. According to this anatomical system the facial expressions are broken down into individual muscle movements knows as action units (AUs). The analysis done based on AU is one of very few techniques available in evaluating real time emotion expressions. Thus, while reviewing through the previous literature, considerations are given in analyzing two significant aspects such as,

1. The evaluation on FAU and their intensity.
2. Determining the emotion level / intensity of facial emotions.

A picture containing diagram

Description automatically generated

Figure 1.2.1 AU variations with varying emotion levels.

### Evaluation of Facial action units and their intensity.

According to FACS, AUs are categorized into three as,

1. Head movement-based AU.
2. Facial movement-based AU.
3. Eye movement-based AU.

Diagram

Description automatically generatedIn this research the main focus lies on the 17 AUs that depict separate facial movements regarding the raising and lowering of brows, movement of lips and many more. Such minute description of facial features could be helpful in assessing subtle emotions very accurately. Shown below in Figure 1.2.1.1 are some of the FAUs coded by the FACS.

Figure 1.2.1.1 Action units of FACS.

Numerous attempts have been taken in improvising the ability to detect AU in facial features. Study [12] focuses on automatic detection of AUs and addresses the difficulties faced by the existing AU detection mechanisms in learning the facial features and provides a comprehensive study on the AUs controlling head and face movements of adults. They present a dynamic patch-attentive deep network (Figure 1.2.1.2) that learns attending to specific patches for the detection of specific AUs. However, it is also discussed that this approach is tested majorly on adults for a single database where non frontal variation in head pose is relatively limited.

In study [13], researchers analyzed how AU detectors perform when they are transferred to domains in which they are not trained such as observational scenarios, participant diversity, video resolution etc. Even though AU detectors performed well when trained and tested within the same domain, they concluded the presence of local specificity to be greater than cross domains in AU detection where they stated more concerns should be taken when using the classifiers from one domain to another. Research [14] details out that the major challenge in AU recognition approaches are the lack of AU annotations due to less domain expertise. Therefore, they propose a knowledge driven method for jointly learning multiple AU classifiers without AU annotations based on prior probabilities of AUs.

Diagram

Description automatically generated

Figure 1.2.1.2 Dynamic patch-attentive deep network.

Source : I. Onal Ertugrul Front. Comput. Sci 2009 [12]

The previous work [15] has made an extraordinary effort in providing a deep learning-based attention and relation learning framework that aids in detecting the AU along with the intensities. The experiments prove that this approach performs well for cross data sets with differing domains and also has the capability in detecting the AUs in faces even if the face is partially visible. However, it should be noted that all data sets trained and tested for this approach are based on adult data and specifically this approach requires AU labels for detection.

Even though there exists numerous attempts taken to detect AUs by various implementations, understanding the strength of AUs has not gained much attention. Therefore research [16] presented a regression-based AU intensity estimator that uses Gabor moments via regression aiding the optimization of AU intensity predictions.

The view of the face could be one important aspect that needs to be considered when evaluating AUs and the facial expressions thereby all the previous research discussed above, focuses only on the frontal view of the face. Amidst that, a new attempt was taken in research [17] where a fine tuned VGG – face network was trained on cross view facial images to improve AU detection further in different views as shown in Figure 1.2.1.3.

![Diagram

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Source: C. Tang et al IEEE 2017[17]

Figure 1.2.1.3 Face cross view AU detection mechanism.

Even though there exist various attempts in detecting the AUs and their intensity in facial features, less work has been carried out in identifying the mappings of AU stimulation relative to the facial emotions.

Research [18] focuses on building FER systems that can recognize facial expressions of emotions, attitude, and mood by detecting the AUs in videos. While analyzing these aspects they use a point localization method to identify what AUs are activated, whether the AU activated is in the onset, apex or offset phase. As shown in Figure 1.2.1.4, the temporal analysis of AU12 corresponding to smile movements are manually coded as onset depicted by the yellow area, apex depicted as green area and orange depicted as offset region. Individual Gentle boost templates built from Gabor wavelet features are used where final temporal segments are recognized via support vector machines (SVM). But it is observed that this approach also has a major concern on adult features and no specific consideration is given in unifying this approach for children.

Chart, box and whisker chart

Description automatically generated

Source: M. Valstar IEEE 2006 [18]

Figure 1.2.1.4 Temporal analysis of smile AU

Another study [19], analyzes further on AU detection to explore the correlations among AUs and facial expressions. They have presented an AU - Expression knowledge constrained representation learning framework as shown in figure 1.2.1.5, which aids in detecting AU activated during emotions without AU annotations facilitating facial emotion recognition. This approach produced outperforming results not only in lab-controlled environments but also in uncontrolled environments. Yet this approach too deals with adult data where age constraints are not taken into concern.

Diagram

Description automatically generated

Source: T. Pu, T. Chen IEEE 2021[19]

Figure 1.2.1.5 AUE - CRL Framework

Considering the annotation of AU and its intensity for emotion expression analysis, research [20] presented a deep CNN model which comprises of two networks where the first network focusses on the AU occurrence and the next on both the AU occurrence and intensity. Finally, a model that could detect AU and its intensity is produced as the final outcome.

When focusing on the study of children, their facial expressions from growth are very subtle and mild therefore more attention is needed to understand their emotions precisely. A previous work [21], present a pilot study to measure facial expressions in infant – mother interaction in an automated manner. They elaborate on the associations in anatomy such as eye constriction, smile strength and mouth opening during the interaction between a 6-month-old infant and mother. Even though an analysis on the interaction is done, no specific focus is paved on understanding how facial interactions happen among children.

Research [22] states that the need to understand craniofacial anomalies in child face are of special interest as any distortions caused in expressing emotions can bring difficulties to parents in understanding the signals given by children interrupting parent-infant interaction. Therefore, in order to analyze this aspect, the facial expressions of infants were coded by a system known as baby FACS [23]. Even though this approach is on children, there is no evidence of validity on this approach when compared to FACS. Further baby FACS is proprietary which limits its accessibility to high income countries. The study [22] , also elaborates on the emotional development of infants where they state the presence of FACS AUs in infants during the prenatal and neonatal smiling stages as shown in figure 1.2.1.6 which further adds validity to our approach of utilizing FACS AUs for child emotion analysis.

![Diagram

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Source: S. Mitsven 2020 [22]

Figure 1.2.1.6 AU visibility in infants.

In study [24], a multi label CNN approach is used to investigate on the action units activated in random behavior of infants. Having implemented the architecture as shown in figure 1.2.1.7, they were able to detect 9 main AUs that can be tracked in infants with a Kappa ranging from 0.69 to 0.93. This study also brings evidence that the association between emotions and AU differ distinctly when comparing adult and children.

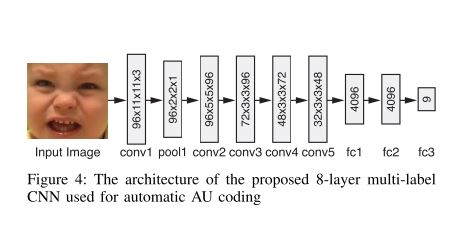


Figure 1.2.1.7 Infant AU coding with Multilabel CNN.

Source : Z. Hammal ACII 2018 [23]

### Determination of Facial emotion levels and Intensities.

![Graphical user interface, application

Description automatically generated](data:image/jpeg;base64,/9j/4AAQSkZJRgABAQEAYABgAAD/4RDcRXhpZgAATU0AKgAAAAgABAE7AAIAAAAGAAAISodpAAQAAAABAAAIUJydAAEAAAAMAAAQyOocAAcAAAgMAAAAPgAAAAAc6gAAAAgAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAEtvdmkhAAAFkAMAAgAAABQAABCekAQAAgAAABQAABCykpEAAgAAAAMzNAAAkpIAAgAAAAMzNAAA6hwABwAACAwAAAiSAAAAABzqAAAACAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA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more interest emerged on exploring human facial emotions in the field of HCI, various attempts were taken in enabling the ability of machines to detect specific features that drives the emotion levels / intensity. In the study [25], the researchers have attempted the detection of emotion and emotion intensity in three emotions namely happy, surprise and disgust as shown in figure 1.2.2.1 where an active appearance model (AAM) is used for feature extraction. The features extracted are then fed as inputs to an SVM classifier having the radial basis function (RBF) as the kernel. This study also provides a comparison between human and machines on the recognition ability of emotion and emotion intensity which concludes that the AAM-SVM classifier is more accurate in categorizing the emotions compared to human but were less accurate in categorizing the emotions into intensities (Figure 1.2.2.2). Another distinct factor seen here is the categorization of emotion intensities as individual levels namely level 1, level 2, level 3, and level 4 which doesn’t imply a precise meaning in human context.

Figure 1.2.2.1 Emotion intensity via AAM - SVM

Source: I.Marian Beszedes IEEE 2007 [24]

[24]

Figure 1.2.2.2 Comparison of emotion and emotion level via AAM - SVM

Research [26] also proposed a new approach in estimating the emotion and emotion intensity where the major analysis was focused on the nature of smile and its intensity. The geometric facial features from spontaneous videos of adults were extracted using Luxand face SDK and fed to a Naïve Bayes classifier for ensemble learning. The intensity of the expression was calculated based on the weight of each classifier in weighted voting. One notable factor here is the usage of geometric facial features for the prediction rather than appearance-based feature. This prevents the model sensitivity to any lighting conditions. As shown in figure 1.2.2.3, feature values were computed as a cosine of the angle considering the positional relation between three facial features at a time. The emotion intensity predictions obtained in this study are normalized to discrete values ranging from 0 to 1 which is also in close accuracy to the manual emotion intensities. However, this study conducted focusing on adults, stated that the consideration of age and gender characteristics on this system to be carried out as their future work.

![A close-up of a clock

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confidence](data:image/jpeg;base64,/9j/4AAQSkZJRgABAQEAYABgAAD/4RDcRXhpZgAATU0AKgAAAAgABAE7AAIAAAAGAAAISodpAAQAAAABAAAIUJydAAEAAAAMAAAQyOocAAcAAAgMAAAAPgAAAAAc6gAAAAgAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAEtvdmkhAAAFkAMAAgAAABQAABCekAQAAgAAABQAABCykpEAAgAAAAM4MQAAkpIAAgAAAAM4MQAA6hwABwAACAwAAAiSAAAAABzqAAAACAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA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Figure 1.2.2.3 Geometry based feature points.

Source: H. Nomiya IJNDC 2016 [25]

The research [27] proposes a dynamic ranking model known as Conditional ordinal random field (CORF) which extracts Haar-like features thereby providing emotion intensity predictions as ordinal scales such as neutral, increasing and apex. Even though the study was done for adults without any age considerations the model provided comparable results to ground truth.

In research [28], a ranking model that has the ability to predict both emotion and emotion intensities is proposed. Here the ranking function is utilized for emotion recognition whereas the ranking scores are utilized in estimating the emotion intensity. The researchers also addressed that they were unsuccessful in classifying emotions into levels using the FAUs as the FACS doesn’t give a quantitative measure between the level therefore Haar-like features were majorly considered for extraction. Shown in figure 1.2.2.4 is an overview of the ranking model framework implemented.

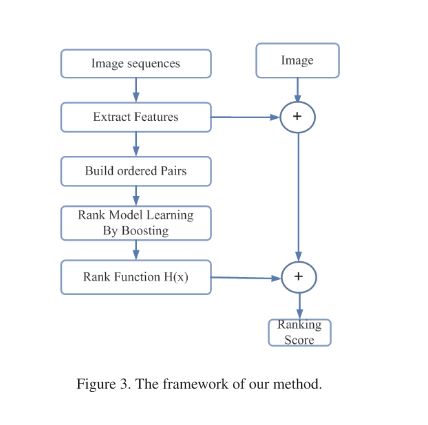


Figure 1.2.2.4 Ranking model for emotion and intensity prediction.

Source: P.Yang IEEE ICCV 2009 [27]

Another prominent work in previous study [29], carried out an emotion level analysis where they were able to predict the emotion levels in an ordinal manner such as peak, moderate and high for three emotions happy, surprise and sad with the usage of adult images. The major techniques used are based on AU where the intensity prediction is done by an exploratory factor analysis (EFA). The random forest classifier (RF) fitted was able to provide an accuracy of 87%. However, this work aims consideration of emotion level analysis of growing children and identification of AU contribution on children with age as their future work.

In [30], images of adults are analyzed to predict the six basic emotions and their emotion levels expressed as ordinal scales namely onset, offset and apex. The multi-level deep CNN model implemented consists of two modules as Expression net CNN and Intensity net CNN. Expression net CNN is used for emotion classification and Intensity net CNN is used for emotion level classification. This model yielded a good result compared to the other approaches, even though parallel processing of both emotion and emotion level is not possible via this implementation.

Research [31] proposed a multi label CNN model which could predict the emotion and emotion level from the images of adults simultaneously. The CNN model proposed here is a combination of Binary cross entropy loss and island loss functions further pretrained with VGG-16 thereby providing an excellent performance in emotion and emotion level prediction. The haar-like features are considered as the feature inputs to the model. As the model is less performative on unseen data, generalizing this model for some spontaneous data is considered as the future work. The figure 1.2.2.5 provides a comparison on the performance between the proposed model and other models which has emotion and emotion intensity prediction capabilities.

![Table

Description automatically generated](data:image/jpeg;base64,/9j/4AAQSkZJRgABAQEAYABgAAD/4RDcRXhpZgAATU0AKgAAAAgABAE7AAIAAAAGAAAISodpAAQAAAABAAAIUJydAAEAAAAMAAAQyOocAAcAAAgMAAAAPgAAAAAc6gAAAAgAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAEtvdmkhAAAFkAMAAgAAABQAABCekAQAAgAAABQAABCykpEAAgAAAAMyMQAAkpIAAgAAAAMyMQAA6hwABwAACAwAAAiSAAAAABzqAAAACAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA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234o/6FD/ypxf4V0tFHt6f/PqP/k3/AMkH1ar/AM/pfdD/AOQOa/tvxR/0KH/lTi/wo/tvxR/0KH/lTi/wrpaKPb0/+fUf/Jv/AJIPq1X/AJ/S+6H/AMgc1/bfij/oUP8Aypxf4Uf234o/6FD/AMqcX+FdLRR7en/z6j/5N/8AJB9Wq/8AP6X3Q/8AkDmv7b8Uf9Ch/wCVOL/Cj+2/FH/Qof8AlTi/wrpaKPb0/wDn1H/yb/5IPq1X/n9L7of/ACBzX9t+KP8AoUP/ACpxf4Uf234o/wChQ/8AKnF/hXS0Ue3p/wDPqP8A5N/8kH1ar/z+l90P/kDmv7b8Uf8AQof+VOL/AArN1s+I9cgtopvDVxbi2uorpTBqcGWaNtyg7kPGR2x9a7eij29P/n1H/wAm/wDkg+rVf+f0vuh/8gc1/bfij/oUP/KnF/hR/bfij/oUP/KnF/hXS0Ue3p/8+o/+Tf8AyQfVqv8Az+l90P8A5A5r+2/FH/Qof+VOL/Cj+2/FH/Qof+VOL/Culoo9vT/59R/8m/8Akg+rVf8An9L7of8AyBzX9t+KP+hQ/wDKnF/hR/bfij/oUP8Aypxf4V0tFHt6f/PqP/k3/wAkH1ar/wA/pfdD/wCQOa/tvxR/0KH/AJU4v8KP7b8Uf9Ch/wCVOL/Culoo9vT/AOfUf/Jv/kg+rVf+f0vuh/8AIHNf234o/wChQ/8AKnF/hR/bfij/AKFD/wAqcX+FdLRR7en/AM+o/wDk3/yQfVqv/P6X3Q/+QOa/tvxR/wBCh/5U4v8ACj+2/FH/AEKH/lTi/wAK6Wij29P/AJ9R/wDJv/kg+rVf+f0vuh/8gc1/bfij/oUP/KnF/hVSC88TQ6pdXx8LyyPcKiBH1OHbEq54XC9ySTnJyfQADsKKPb0/+fUf/Jv/AJIPq1X/AJ/S+6H/AMgc1/bfij/oUP8Aypxf4V0Ns8strFJcQ+RMyBpItwbYxHK5HXB4zUlFZ1KkZr3YKPpf9WzalSnB3lNy9eX9EgooorE3CiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKAP//Z)

Source: O. Ekundayo Peerj Computer Science 2021 [30]

Figure 1.2.2.5 Comparison of VGG ML - CNN with other models.

## 1.3 Research Gap

According to the literature review, it is evident that even though facial emotion analysis has been an emerging field of research in the domain of HCI there exist numerous drawbacks and misconceptions in the systems developed previously. Any FEE or FER system that was developed has not taken the varying age categories into consideration, instead the analysis is done having the assumption of adults and children to have similar growth in mental health. Implementations done had completely used adult data for testing purposes which will not be appropriate to assess child emotions as there are several clinical proofs [6] stating about the differences in the perception of emotions in adults and children.

Even though there exist a few number of studies that focuses on both emotion and emotion level prediction [25], it is seen that no major concern is given in assessing the child emotion levels specifically. Moreover, the attempt of assessing emotion levels through videos has not provided results as expected even though the systems performed well with static images. Yet identifying the emotion level only through a single frame seems to be not convincing enough as emotion levels are very subtle and mild causing difficulty to be tracked in a single frame.

All the previous work addressed in the literature review discusses the usage of various facial features categorized as geometric features and appearance-based features which are more of less real time emotion detection mechanisms but only few of them attempted in analyzing the emotion levels through FAUs. Yet those researches [29] too are based on analyzing adult AU and not specifically on children.

Finally, even though there are numerous implementations proposed in this domain, there do not exist any mobile or web application that could assist parents and care takers to assess the real time emotion level of children while understanding the improvement of muscle movements such as AU through their videos which is specific to the age group of children.

Provided below in Table 1.3.1 is an overview of the research gaps noticed in previous works through the literature review. The previous works considered for comparison are provided as columns with their respective literature added as references.

Table 1.3.1 Research Gap index

|  |  |
| --- | --- |
| **AVAILABLE** |  |
| **NOT AVAILABLE** | Close with solid fill |

Table 1.3.2 Literature Survey Research Gap

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **PREVIOUS WORK** | [25] | [32] | [27] | [28] | [29] | [33] | [30] | [31] | **Chezer Emotion Analyzer** |
| Age consideration. | Close with solid fill | Close with solid fill | Close with solid fill | Close with solid fill | Close with solid fill | Close with solid fill | Close with solid fill | Close with solid fill |  |
| Child Emotion Analysis | Close with solid fill | Close with solid fill | Close with solid fill | Close with solid fill | Close with solid fill | Close with solid fill | Close with solid fill | Close with solid fill |  |
| Dynamic source analysis. | Close with solid fill |  |  | Close with solid fill | Close with solid fill |  | Close with solid fill | Close with solid fill |  |
| AU based Emotion level assessment. | Close with solid fill | Close with solid fill | Close with solid fill | Close with solid fill |  | Close with solid fill | Close with solid fill | Close with solid fill |  |
| Ordinal Emotion level. | Close with solid fill | Close with solid fill |  | Close with solid fill |  |  |  |  |  |
| Emotion and emotion level prediction. |  |  | Close with solid fill |  |  | Close with solid fill |  |  |  |
| Action unit detection |  | Close with solid fill | Close with solid fill | Close with solid fill |  | Close with solid fill | Close with solid fill | Close with solid fill |  |

### 1.3.1 Novelty

According to the research gaps observed, there is a dearth of studies that provides a sufficient amount of attention in assessing the child in terms of their emotional development. Moreover, there appears to be a gap in the research that has been conducted previously in analyzing human facial emotions along with the level of emotion expressed using AUs activated in the face.

Furthermore, there are no studies or approaches proposed to analyze the AU traits and changes in emotion levels according to the age group of individuals. Instead, most of the research consider adults and children to show similar traits in their emotional development which proves to be wrong by some clinical studies which was discussed in the literature review and thereby individual attention is required to prevent any mental disorders right from childhood. As per the current knowledge it is evident that no single solution has been developed to achieve all the important facts as listed in Table 1.3.2

As a result, this study focuses on addressing the research gaps observed to provide a full-fledged automated system that aids parents and care takers assess child emotion levels in an unbiased manner right from the natural setting of the child. Prominently, providing the ability to assess children based on their age groups will help parents understand the actual mental condition of the child where they can come up to a conclusion if the child is attaining the right milestones for their age and the causes of developmental distortions if any. Rather than extracting appearance-based features, the choice of FAU will be a great value to the system aiding in understanding the real time emotion levels and the muscle movements while expressing the emotions. This application is implemented in a child friendly manner where it will be also available for use by any individual since it will be delivered on a reasonable cost setting.

## 1.4 Research problem

The implementations currently available for facial emotion level expression analysis are merely trained based on adult data but its support on child emotion level analysis could be inappropriate as studies [1] detail that age is an important factor affecting the variations of facial emotions. Solely when the development of a child is considered, it is evident in the study [5] that all children will not be able to express their emotions in a similar manner since the mental health and cognitive development changes with the inclination of age. Even within the similar age group, the pace of development varies from one individual to another. Furthermore, the analysis of child development needs close observation which aids in the identification of abnormalities and distortions at the right time while preventing other malfunctions and abnormalities that could occur in children related to their mental health thereby paving way for age-appropriate growth and development.

Summarized below are the major research problems to which solutions are proposed as the main objective of this research.

1. Necessity to annotate images expressing emotions based on emotion levels.
2. Develop a technique to identify the AU stimulations mapped with emotion levels.
3. Differentiate the AU stimulations within adults and children.
4. Research and analysis on the impact of age on Child facial emotion level assessment.

Chart, bubble chart

Description automatically generatedA survey conducted among an audience of 50 members gave a good response rate that evidently supported the problem consideration in this research. The majority of individuals who participated in this survey belonged to the age group of 25-30.

Figure 1.4.1 Survey response on the usefulness of Child Emotion analysis

Chart, pie chart

Description automatically generatedAs shown in figure 1.4.1, all the participants of this survey agreed that child emotion analysis is essential in getting an understanding of the normal growth and behavior of the child. The responses include various reasons for their choices which states that facial analysis in children could be helpful to track any signs of aggression or other negative emotions that could result a negative impact to the child and aids treating those at an earlier state. In the responder’s point of view, they stated that facial emotion analysis could be a prominent factor to be understood in creating a healthy environment to their children.

Figure 1.4.2 Survey response on the difference between child and adult Emotion analysis

Approximately 96.7% of responses were in favor to the fact that emotion expression ability between children and adult are different (Figure 1.4.2). When considering the reasons for the response, 76.7% of them stated that age has an effect, 53.3% stated that the child’s development environment has an effect, and a minority stated the reason to be gender.

Chart, bar chart

Description automatically generated

Figure 1.4.3 Survey response on reasons for the emotion difference in adults and children

Chart, pie chart

Description automatically generatedFurther questioning about the convenient way of knowing the intensity of the emotion expressed, 90% of the responders preferred understanding the emotion intensity along with the emotion. Where out of them 73.3% stated that they prefer understanding the emotion level expressed in an ordinal manner rather than interpreting random discrete values which evidences that human prefer insights in a man heuristic manner.

Figure 1.4.4 Survey response on their opinion on Emotion intensity

Figure 1.4.5 Survey response on the scale of emotion intensity prediction

Chart, pie chart

Description automatically generated

Chart, bar chart

Description automatically generatedWhile understanding the opinion of individuals to have an application that could detect emotions in children it was seen that 80% of responders had provided their likeliness towards it on a scale above three. This shows that the presence of such a system would be a valuable solution for timely assessment of child mental health.

Figure 1.4.6 Survey response on an application to track Children emotion

Chart, pie chart

Description automatically generatedA majority of the responders of this survey belong to the medical / health care sector and education sector which firmly evidences that a system to track emotion level could be necessary as they are the individuals who are in close relationship with the growing children.

Figure 1.4.7 Responders of the survey

## 1.5 Research Objectives

Main Objective

An application that could analyze facial emotions thereby assessing the mental wellbeing of child which helps to track the growth and milestone attainment of child easily is the fundamental goal of Chezer – Child emotion analyzer. The major aim of this study is to “Automate the analysis of facial emotion levels of children via FAU” which further focuses on individual age groups of children, thereby assisting parents and caretakers to understand the child’s growth and development while attaining the emotional milestones of one’s age. Shown below in figure 1.5.1 is the functional view of the Emotion level analysis component in the mobile application.

Diagram

Description automatically generated

Figure 1.5.1 Emotion level analyzer integrated with Chezer

Specific Objectives

1. Analysis on the input videos to extract the AU activations.

Collect video sources belonging to children for the emotions happy, sad, disgust and surprise categorized based on the age of children. The age groups to be considered are four – six years and six – ten years respectively.

Generate AU intensities for the data aiding further analysis.

1. Feature Engineering

Dimension reduction and statistical analysis to identify the AUs prominently activated for the emotion levels expressed. Validate the approach of AU detection against the state-of-the-art information found in the literature. The two main approaches for comparison are

1. Exploratory factor analysis.
2. Principal component analysis.
3. Utilize the AUs identified, to annotate the available data with emotion level labels such as high, moderate, and low which could be used for model training.
4. Train machine learning models specific to age, using the annotated dataset generated to predict the emotion levels of video sources of children.
5. Incorporate the model to a gaming mobile application which assists emotion level predictions of the child while he / she plays the game.

# METHODOLOGY

## Overview

In clinical settings, Chezer – Child emotion analyzer is an application that can be utilized to assess the children’s psychological and cognitive development in a timely manner.

Initially, the analysis is initiated by adding the details of a child along with the age group they belong to. Once the child plays the game to express the emotions, the activity of the child is recorded capturing the facial emotion variations throughout the game. The video captured is passed to Emotion level analysis component for further emotion assessment.

Diagram

Description automatically generatedThe emotion level analyzer aids in assessing the emotion level variations along with the facial muscle activation while the child plays the game where insights are provided to the user as a dashboard thus providing a comprehensive analysis on the emotional development of the child with respect to his / her age group.

Figure 2.1.1 Overall System Diagram

## Component Development.

The Emotion level analyzer component was developed in the aim of overcoming the research gaps seen in other implementations as discussed in Section 1.3. The approach of this component in detecting the emotion level is designed in a way as to overcome two main problems

1. None of the datasets are annotated based on their emotion levels. Instead, all existing datasets have emotion annotations which restricts successful research in the context of emotion level.
2. Text

   Description automatically generated with medium confidenceAmong the 17 AUs present in face, not all of them influence the emotion levels. Therefore, identification of the right set of AUs is also important for an accurate prediction.

Figure 2.2.1 Emotion level analyzer design diagram.

The approach followed in developing the models for emotion level analysis as shown above in Figure 2.2.1 is discussed further in the upcoming sections.

### 2.2.1 Data Preparation

The data is prepared considering two different aspects such as

1. AU stimulation assessment

Initially, the images belonging to the CAFÉ dataset were manually separated into four categories as images showing happy, sad, surprise and disgust emotions facilitating the assessment of AU stimulation in emotions.

1. Emotion level assessment.

The images categorized based on emotions, were further separated based on the emotion levels that is visible to the human eye. For example, images belong to happy emotion were investigated further and separated to three categories as high happy, moderate happy and low happy which aids in AU stimulation assessment in emotion levels. This image separation was under one condition such that any image belonging to one level of emotion cannot be included under another level ensuring the presence of independence of observations.

A close-up of a child smiling

Description automatically generated with medium confidenceA picture containing person, indoor, posing

Description automatically generatedOnce the data was prepared as such, the action units and intensities corresponding to them were generated using Open Face where the face is detected for feature extraction.

Figure 2.2.1.2 Action unit detection.

Figure 2.2.1.1 Frontal view of face detection.

### 2.2.2 Feature Engineering - EFA

According to the FACS, 17 AUs are detected in the face through the Open face tool kit but not all facial movements highly influence a particular emotion or emotion level. Therefore, in the aim of defining the AUs that gets stimulated during a child emotion two techniques were followed for AU detection namely Exploratory Factor analysis (EFA) [34] [35] and Principal component analysis (PCA) [36]. These techniques described further in upcoming sections, facilitate not only dimension reduction but also establishes the underlying dimensional relationships among the variables and provides validity to the results.

1. **Exploratory factor analysis.**

This technique is exploratory in nature, which implies that the researcher need not have prior expectations of the number of variables contributing for a factor and can explore the main dimensions, thereby generate a theory from a large dataset which could be represented by a limited number of factors. Prior to EFA, the suitability of data is investigated.

1. **Analysis on data suitability**

The sample data generated consisting of happy, sad, disgust and surprise emotions should be having at least 200 - 300 data points to obtain valid results.

The relationships between individual variables are analyzed further through a correlation matrix. The factor analysis is feasible only if the correlation among variables are greater than 30%. Finally, two tests are done to assess the data suitability. They include Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett’s test of Sphericity.

The KMO test measures the sampling adequacy for each variable in the model. This results in an index which ranges from 0 to 1 where results are interpreted based on the conditions mentioned in Table 2.2.2.1

Assuming KMO value = x

Table 2.2.2.1 KMO Test inference.

|  |  |
| --- | --- |
| 1.0 ≥ x ≥ 0.7 | Sampling is adequate |
| 0.7 > x ≥ 0.2 | Sampling is not adequate and some remedial action on the data needs to be done. |
| x < 0.2 | Sampling indicates factor analysis is not possible. |

The Bartlett’s Test of Sphericity determines if the data is suitable for data reduction techniques validating if the features reduced would be meaningful based on the hypothesis mentioned in table 2.2.2.2

Table 2.2.2.2 Bartlett’s Test of Sphericity inference.

|  |  |
| --- | --- |
| H0 | Variables of the dataset are not correlated. |
| H1 | Variables of the dataset are correlated. |
| The p value should be significant (p < 0.05) implying data suitability | |

Shown below in figure 2.2.2.1 are the indexes obtained on conducting the test for the dataset, thereby confirming the data suitability for factor analysis.

Table

Description automatically generated

Figure 2.2.2.1 KMO and Bartletts index for dataset.

1. **Data rotation and factorization**

Next, the feature in the dataset is rotated and extracted to structure them into individual factors. There exist numerous ways to extract factors at this step such as maximum likelihood, alpha factoring and generalized least square. The extraction method chosen in this approach is Maximum likelihood as it tends to extract real factors in the sample without considering any hypothetical reasons.

1. **Factor visualization**

Once the extraction is completed, the number of factors the data produced are determined. Approaches used for this are Kaiser’s criteria ( Eigen values > 1 rule), Scree test and cumulative percent of variance analysis.

1. **Feature extraction**

Once the distinct number of factors are extracted, it was checked if one AU relates to more than one factor. In order to fine tune the results obtained, a rotation is done where the high item loadings are maximized, and low item loadings are minimized thereby a more interpretable factor analysis solution can be obtained. The rotation method used is orthogonal varimax rotation which results in factor structures which are uncorrelated.

1. **Factor Interpretation**

Once the features undergo factorization, the final step is to interpret the factors and label them necessarily. The labelling of factors is very subjective and depends on the researcher’s definition. Therefore, for this the well accepted FACS is used for validation and comparison where the final set of factors happy, sad, disgust and surprise were identified with the respective AUs influencing them.

1. **Principal Component Analysis.**

In carrying out the PCA analysis too, the five steps followed in EFA were followed to interpret the factors and the features that resulted, which were further compared with the FACS to determine the final set of factors.

### 2.2.3 Emotion level stimulation – T test Analysis

Once the AUs related to emotions are identified using the EFA and PCA analysis as explained in Section 2.2.2, those AUs are utilized further in analyzing the emotion level stimulations. For this purpose, the data set that was prepared with AU stimulations consisting of varying emotion levels are utilized. An independent sample t test is done using the AUs found by EFA and PCA aiding in the identification of the AUs that influence the emotion levels. Before this process was initiated there are some assumptions which were investigated to check the data suitability for t test analysis as illustrated below in table 2.2.3.1.

Table 2.2.3.1 T test assumptions.

|  |  |  |
| --- | --- | --- |
| **Assumption** | **Details of Data** | **Suitability** |
| Dependent variable should be measured on a continuous scale. | Action unit intensities are continuous variables |  |
| Independent variable should consist of two categorical variables | Independent categories considered are emotion levels high and low. |  |
| Presence of independence of observations. | The images categorized under high emotion are not again included to low emotion. |  |
| There should be no significant outliers. | Outliers detected are removed. |  |
| The dependent variable should be approximately normally distributed for each group of the independent variable. | Skewness, Kurtosis and Shapiro wilks test is done to check normality |  |
| Presence of homogeneity of variances. | Levens test is done to check for homogeneity of variance, |  |

Once the suitability of data for t-test is verified, the independent sample t-test was done by following the steps as illustrated below.

Initially AU intensities generated for high happy and low happy dataset are combined and the AUs that are detected to be influencing happy emotion through the EFA analysis, are passed as the test variables. The categorical variables high happy and low happy are passed as grouping variables. Then the results generated are interpreted by hypothetical inferences as shown in table 2.2.3.2 where the AU stimulation for emotion levels are concluded based on the significant (p) value obtained.

Table 2.2.3.2 T test inference.

|  |  |
| --- | --- |
| H0 | The significant values for variances are equal. (The AU considered has no influence on emotion level) |
| H1 | The significant values for variances are unequal. (The AU considered has an influence on emotion level) |
| The p value should be significant (p < 0.05) thereby rejecting H0 concluding AU causes an impact in emotion level. | |

This approach is followed for every AU identified for happy emotion stimulation and thereby the AUs influencing the variations of happy emotion levels are identified. A similar approach is followed for the emotions sad, disgust and surprise.

The EFA and T test analysis, helped detection of important AUs influencing the emotion and emotion levels among the 17 AUs eradicating one major problem that was faced in previous research which is the identification of influencing AUs.

### Emotion level Annotation – Clustering mechanism.

Once the AUs influencing emotion levels are identified by EFA and T test analysis, the dataset to be trained is prepared with Emotion level annotations which is also a major cause for the lack of research in the domain of emotion level analysis.

The videos of children expressing the emotions happy, sad, surprise and disgust in different levels such as high, low, and moderate are split into frames and then incorporated to the K-means clustering algorithm where the AUs identified via t test are used as the clustering parameters.

Once the clusters are evaluated manually, it is seen that the frames belonging to a video are clustered into three groups based on the level of emotion observed. On such aspect the frames of a videos from the LIRIS and Emo react database are annotated base on the emotion levels thereby resulting an annotated dataset for emotion level classification.

### Emotion Level Detection – Machine Learning

Once a dataset annotated with emotion levels is prepared, classification algorithms such as SVM, Random Forest (RF) and K-Nearest neighbor (KNN) were used in training the model with a train test split ratio of 7 : 3. The hyper parameters of the model are further tuned to provide precise emotion level analysis with a good accuracy when a video input is fed to it.

The major hyper parameter tuning techniques used are GridSearch CV and RandomizedSearch CV. Since the data set is not too large, setting the parameters manually wouldn’t be exhaustive therefore Grid search CV is implemented. On the other hand, RandomizedSearch CV has the ability to match random parameters and provide the best set of parameters that optimizes the model therefore this technique is also incorporated to compare the model accuracy.

### Age wise Emotion level detection.

On the aim of analyzing the AU stimulations when there is a variation of age in children, the steps demonstrated in Sections 2.2.1 to 2.2.5 were performed for a data set which was prepared with age wise separation where the results and variations will be illustrated further in detail in Section 4 – Results and Discussion.

## Key Pillars

* **EFA and PCA analysis for Emotion based AU stimulation identification.**

EFA and PCA are major dimension reduction techniques, that includes multiple methodologies that aid in explaining how a certain number of observed variables constitute for a factor. The main aim of utilizing these techniques is to represent a set of original variables by a small set of important factors thereby maximizing the representability of the original data points. Emphasizing further on factor analysis, there exists two techniques namely confirmatory factor analysis (CFA) and EFA. CFA is a good technique when a researcher is aware of the factors needed and the feature variables influence responses that imply based on an existing concept. EFA, as its name implies is exploratory in nature implying that the researcher need not have prior knowledge on the number of factors that would result through the dataset. There exists various theoretical concepts that reveal the AUs contributing for an emotion but had failed to prove their validity. EFA would be a good choice here since there is no clear expectation about the correlation between AUs in defining an emotion. Moreover, it is also notable that EFA is specified to be useful in analyzing complex concepts that have some difficulties in measurements such as mental health, development and assessment of psychometric properties and other clinical aspects [37]. EFA not only is used as a dimension reduction technique, but it also aids in identifying the inter relationships of the features that constitute for a factor [38].

On the other hand, focusing further on PCA, it is the most common statistical technique used in recognizing underlying patterns in areas such as signal and image processing which mainly deals with dimension reduction and data compression approaches[39]. As the AU stimulation in emotions are detected through images, PCA analysis method was used as a way to provide validity to the results of EFA which has no prior evidence on its ability in feature inference with respect to images. There also exists various differences in the approach of EFA and PCA which was further examined thereby providing validity to the novel technique presented in identifying AU stimulation influencing emotion levels.

* **Random Forest Model to predict Emotion levels.**

A machine learning model is chosen as the classifier to detect the emotion levels seen in child videos. The choice of an ML model rather than a DL model was made considering various aspects such as the performance, dataset, nature of input features, time, and efficiency. As the dataset is itself annotated via a novel approach the dataset available for analysis is limited which drives the choice of a ML model instead of a DL model. Moreover, another specific reason of choosing an ML model over a DL model is that, even though the predictions were based on the frames of a video the feature inputs were not the dimensions of the image, but they are the AUs extracted via the expression seen in the image. The machine learning algorithm used for this purpose is RF as the necessity of the model was to predict the presence of an emotion level seen in the video. It is a technique used mainly for classification and regression-based problems. This model utilizes ensemble learning techniques through which several classifiers can be combined and optimized to solve complex problems. The algorithm and predictions were further enhanced by the proper choice of hyper parameters by using hyper parameter tuning techniques such as Grid search CV. Further details on the choice of this algorithm will be discussed under the results sections with necessary evidence of validity.

## Dataset and Resources

Child data in sufficient amounts is the most important resource required to achieve the objectives of this research. Through a thorough literature review, several child databases were identified where further details on age of some databases were requested from the authors. Illustrated below are the child databases utilized in Emotion level analyzer.

1. **Child Affective Facial Expression (CAFE) [40].**

CAFÉ is an image dataset which is used in detecting the action unit stimulation for the emotions happy, sad, surprise and disgust in three intense levels as high, moderate, and low. The dataset contains 1193 images that contains variation of the seven basic emotions. The emotions are performed by 154 models belonging to an age range of 2 to 10 years where 90 of them were females.

AU is the muscle activation seen in the face during an emotion expression, therefore capturing the movements even during the subtle emotion level changes was a great challenge when utilizing the video dataset. Therefore, the choice of CAFÉ dataset aided in precise and accurate emotion level AU stimulation investigations.

1. **LIRIS Children Spontaneous Facial expression [41]**

LIRIS is a video dataset which is used in training the emotion level prediction model for the emotions happy, sad, disgust and surprise in three intense levels as high, moderate, and low. The dataset contains 215 videos where the six basic facial emotions are expressed by 12 models. The models consist of a mean age of 7.3 years. The videos utilized are recorded at a frame rate of 25 frames per second where each video is recorded during an instance where a child watches a movie that invokes the basic facial emotions. Importantly the videos recorded shows a clear visibility of the change in emotion levels from low to high.

1. **Emo react database [42]**

Emo react is a video dataset that is used in training the model for emotion level predictions. It contains 1102 videos annotated for 17 different emotions expressed by 30 models belonging within the age group of 4 to 14 years. The videos are recorded at a frame rate of 23.97 frames per second where each video is recorded during an instance where a child reacts for certain instances such as movies, toys, games, food etc. Utilizing this video dataset for training purpose helps to train the model to predict emotion levels in spontaneous expressions rather than posed thereby further improving the efficiency of the system.

1. **Testing data.**

Once the models are trained for emotion level predictions, it was tested with videos for further enhancements. On such aspect, data was collected from neighboring day care centers, where the model was tested on predicting their emotion levels thereby further enhancing the model. Once the gaming application was developed, it was further allowed to be played by children belonging to different age groups in testing the model’s performance on the age analysis further.

## Testing and Implementation

### Testing

Once the models are implemented as illustrated in Section 2, the performance of the model is tested by carrying out unit tests and integration tests in order to identify further fine tunings to be done to the model with regard to emotion level predictions.

The unit tests were carried out by testing sample videos of children collected from day care centers and pre schools while capturing their emotion expressions in a spontaneous environment whereas the integration testing was conducted by allowing the child to play the Chezer- mobile game in a natural setting. Initially, the snippets of videos were first analyzed individually thereby testing the emotions separately. Finally, the overall video was tested to analyze the ability of model to differentiate levels among 4 different emotions too.

Illustrated in Table 2.5.1.1 are a set of test cases that were conducted to determine the prediction accuracy of the Emotion analyzer model. As the video snippets are analyzed for testing, sample frames extracted for a time duration of 4 seconds (20 frames) are added for illustration purposes.

Table 2.5.1.1 Emotion Analyzer - Test cases

|  |
| --- |
| **Test ID: 001** |
| **Test Description:** Frames of a child of age (4-6) in a video showing Happy Emotion. |
| **Test Data:** |
| **Expected Output:** Emotion Level variation from Low happy, Moderate happy to High Happy. (The expected output is based on researcher observance) |
| **Actual Output:** |
| **Test status: Pass** |

|  |
| --- |
| **Test ID: 002** |
| **Test Description:** Frames of a child of age (4-6) in a video showing Surprise Emotion. |
| **Test Data:** |
| **Expected Output:** Emotion Level variation from Moderate surprise to High surprise. (The expected output is based on researcher observance) |
| **Actual Output:** |
| **Test status: Pass** |

|  |
| --- |
| **Test ID: 003** |
| **Test Description:** Frames of a kid of age (4-6) in a video showing Sad Emotion. |
| **Test Data:** |
| **Expected Output:** A variation of levels in Sad emotion (The expected output is based on researcher observance) |
| **Actual Output:** |
| **Test status: Fail** |

|  |
| --- |
| **Test ID: 004** |
| **Test Description:** Frames of a kid of age (4-6) in a video showing Disgust Emotion. |
| **Test Data:** |
| **Expected Output:** A variation of levels in Disgust emotion (The expected output is based on researcher observance) |
| **Actual Output:** |
| **Test status: Pass** |

|  |
| --- |
| **Test ID: 005** |
| **Test Description:** Frames of a kid of age (6-10) in a video showing Happy Emotion. |
| **Test Data:** |
| **Expected Output:** A variation of levels in Happy emotion (The expected output is based on researcher observance) |
| **Actual Output:** |
| **Test status: Pass** |

|  |
| --- |
| **Test ID: 006** |
| **Test Description:** Frames of a kid of age (6-10) in a video showing Surprise Emotion. |
| **Test Data:** |
| **Expected Output:** A variation of levels in Surprise emotion (The expected output is based on researcher observance) |
| **Actual Output:** |
| **Test status: Pass** |

|  |
| --- |
| **Test ID: 007** |
| **Test Description:** Frames of a kid of age (4--6) in a video showing all four emotions Happy, Sad, Surprise and Disgust. |
| A child looking at the camera  Description automatically generated with medium confidenceGraphical user interface, application  Description automatically generatedA child smiling for the camera  Description automatically generated with medium confidenceA child with his mouth open  Description automatically generated with medium confidence**Test Data:** |
| **Expected Output:** A variation of levels in Surprise emotion (The expected output is based on researcher observance) |
| **Chart, line chart  Description automatically generatedActual Output:** |
| **Test status: Pass** |

### Implementation

The Emotion level analysis component supports in providing insights on the emotion levels visible in the child while playing the Chezer mobile application.

Chart

Description automatically generatedGraphical user interface, application

Description automatically generated

1. *Prototype b) Implementation*

Figure 2.5.2.1 Emotion Level variation and visibility

As shown above in Figure 2.5.2.1, once the child plays the FEE game, the user will be able to view the emotion level analysis interface at the end of each level. Here the user will be able to obtain an insight on the variation of emotion levels seen throughout while the child plays the game. In addition, the visibility of emotion levels as a whole with respect to the intensity such as high, moderate, and low can also be observed through this interface.

Graphical user interface, application, table

Description automatically generatedGraphical user interface, application

Description automatically generated

1. *Prototype b) Implementation*

Figure 2.5.2.2 Facial muscle activations

As shown above in Figure 2.5.2.2, once the emotion level variation is viewed the user will be able to see the Activation status (Activated / Not activated) of the AUs influencing the emotion levels thereby getting an insight on the muscle features that cause abnormalities in expressing relevant emotion levels.

## Commercialization.

**Target Audience of the system**

This application is implemented specifically targeting the user groups from the clinical and educational sector where a close relationship between growing children prevail. The system is designed in such a way as to be used by users who have the necessity in assessing and keeping track of child emotional cues in depth. On the other hand, the simplicity of the application enables parents and caretakers too, to assess their child’s emotional traits in an occasional manner.

Most of the individuals in the clinical sector will need to understand the emotional development in detail such as the activation of facial muscles during emotion expressions and the ability and inability to variate their emotion levels. Therefore, anyone as such having the necessity of tracking the emotion level variations of children will be able to use this application.

**Demand and Marketing plan of Emotion level analyzer**

The major motive of individuals in assessing the child emotional well being is to assess the abnormalities before hand and treat them in an earlier period. Therefore, understanding the developmental traits in an unbiased manner is of utmost importance, but in clinical centers when activity-based child assessments are done they tend to be very anxious about the environment and that could lead to false understanding of their mental well being and development. Thereby a mechanism through which children could be assessed in their natural setting, tracking genuine emotional traits has become a major demand.

When analyzing the mental growth of children, identifying how children’s emotions are invoked is one aspect whereas assessing if the child has attained the developmental milestones such as the ability to show their happiness via lip moments etc. at the right age is another aspect. Therefore, the clinicians can assess the attainment of such developmental milestones in children by tracking the activation of AU and their intensities. Also, early abnormalities of children such as the inability to variate their emotion levels can also be tracked using the Emotion level analyzer of this application.

**Steps to market**

1. Introduce the Application freely to the individuals in close contact in assessing Child mental health such as care givers and public health midwives so that we can get an understanding of the efficiency of the application in a small scale while fixing the practical issues of the system if any existed. At the same time, we will be able to provide an awareness on the necessity of such a system in current usage.
2. As the next phase, we could introduce the application to a large scale of medical workers such as public health care workers , medical officers of health , public health nursing sisters which would help us gain a close observation of the effectiveness of the system and how an AU based analysis improves abnormality detection.
3. The system with improved features and further testing can be introduced to the global market which can aid the individuals like parents and child care takers at home to track the mental health of the children effectively.
4. The application can be then sold online with a defined pricing scheme by having contracts with online marketing companies.
5. Enlightening the users, the advantages of this application, social media marketing can provide a great impact in increasing the online sale.
6. The provision of an emotion level analysis through a game could add more value thereby assisting users assess children with ease.

**How to reach out to the audience**

Social media marketing is an immediate step that could be taken to reach out a large target audience in less time. Furthermore, system promotions and awareness on the importance of prior identification of child abnormalities, the impacts that we could face due to untimely mental condition assessment could be helpful in attracting responsible users like parents and clinical professionals.

**Pricing model of the system**

**Diagram

Description automatically generated with low confidence**

Figure 2.6.1 Application pricing scheme

As shown above in figure 2.6.1, the pricing scheme of the application is segmented to three schemes as basic, standard and signature. The basic scheme is free of charge and will be valid for a duration of two months time period where 25 game based video analysis could be done with access to all the functionalities of the application. The free version can be upgraded to the standard package where 50 video analysis could be done with a cost of 300 Sri Lankan Rupees (LKR) per month. The signature package charges 500 LKR where 100 analyses are allowed to be carried out per month.

**Budget**

Illustrated below in Table 2.6.1, is the budget allocated for the Chezer application development and marketing.

Table 2.6.1 Application budget specification.

|  |  |  |
| --- | --- | --- |
| Component | Description | Amount |
| Model deployment | Expense incurred to deploy the models in google cloud platform. |  |
| Data storage | Expense incurred to store video recording of the application in Firebase. |  |
| Marketing cost | Expenses incurred in social media marketing and event plans for system promotion. |  |
| System domain registration | Expenses incurred to register the application domain name. |  |
| Total expense incurred | |  |

## Social, Security, Ethical aspects, and Limitations.

# 3. SOFTWARE SPECIFICATIONS

## 3.1 Requirement Gathering

As the initial approach of development, a questionnaire was distributed to survey the opinions and preferences of individuals in terms of the importance of an automated tool which could assist them in child emotion assessment. Parents, care takers, teachers, medical practitioners, and other individuals working in the health and education sector were among the majority of responders to the survey.

For the purpose of application outcome analysis, videos of children playing the game were collected with the concern of the parents / caretakers. The videos collected were categorized based on the age group of the child, thereby facilitating age wise child emotion level analysis. Different videos of children expressing emotions happy, sad, surprise and disgust in different intense levels were collected separately and sorted to frames for analysis. In addition to it, the model training was carried out by utilizing the available child datasets that were separated based on age.

## Functional and Nonfunctional Requirements.

Through the requirement gathering phase, there are certain considerations provided in implementing the functionality of the model. The Table 3.2.1 provides an overview of the functional requirements.

Table 2.5.2.1 Emotion level analysis - Functional requirements

|  |  |  |
| --- | --- | --- |
| **Requirement ID** | **Requirement Specification** | **Addressing the Requirements** |
| **1** | Real time data capture. | The model should be able to detect the face of the child in Real time where snippets of individual emotion expression as well as overall emotion expression should be tracked. |
| **2** | Differentiate age variations in emotions | The model should be able to predict the emotion level according to the age of the face detected. |
| **3** | Identify the emotion levels of the four basic emotions | The model should be able to differentiate the emotion levels of happy, sad, disgust and surprise |
| **4** | Identify emotion levels in a man heuristic manner, | The model should be able to predict emotion levels as high, moderate, and low instead of discrete values. |
| **5** | The overall analysis should be displayed through the user interfaces without any disruptions. | The model should be able to get the user input and provide the accurate result via the application in a timely and user-friendly manner. |

The implemented system will be able to accomplish the non-functional requirements indicated in Table 3.2.2

Table 2.5.2.2 Emotion level analysis - Non-Functional requirements

|  |  |  |
| --- | --- | --- |
| **Requirement ID** | **Requirement Specification** | **Addressing the Requirements** |
| **1** | Security | Since the model deals with facial identities, the privacy should be ensured while the model is deployed in a cloud environment. |
| **2** | Accuracy | The model should be able to provide accurate emotion level predictions and prevent from misclassifications. |
| **3** | Performance | The model should be able to provide the results for the user in a timely and efficient manner thereby supporting the system performance. |
| **4** | Reliability | The model should be fine tuned to minimize misclassifications thereby not misguiding the user in terms of the result as it can lead to improper decisions. |

## 3.3 Software solution and Design

Once the requirements and the different opinions were gathered through the survey, the advantages, and disadvantages that such a system could have, were well analyzed and further ideated to implement the system to achieve the research goal in an efficient manner. Therefore, the software solution to be implemented was designed in two different aspects as given below.

1. **Database Design**

The videos recorded when a child plays the game should be saved to a database where the video can be retrieved in real time for the emotion level assessment once a child concludes playing the game. Therefore, a real time database is required for this purpose which also has a high performance since the application and its functionalities solely depends on the video data collected during the game. Slowness in the game progress or the assessments obtained by processing the video can create boredom and frustration in users. The optimum database solution chosen for this purpose is the firebase storage, which is a real time, cloud hosted database that synchronizes the data in real time to the client.

1. **User Interface / User Experience (UI / UX) Design**

The user interface is the primary interaction point between the user and the application. Especially being an application designed for children, ensuring that the application is both efficient and simple is very essential. As the main purpose of this tool is to assess the child psychological development in terms of emotions, the child should be able to handle the tool in an easy manner preventing any frustrations or difficulties due of the nature of the application.

As the initial phase of UI / UX design, prototyping of the interfaces were done using Figma. During this process, more brainstorming was done where the perspective of children were considered as the first priority. Once the prototype was completed, 10 random users in various other sectors were given the opportunity to test the emotion level analysis component of the application where feedbacks received were further ideated and improvised.

The emotion level predictions along with the AU movements activated while the child plays the game are designed to be displayed as graphs where emotion levels are represented as ordinal scales which is more man heuristic. Indication of muscle movement intensities provides more understanding on the abnormalities in child. At every analysis of the application voice commands are incorporated guiding the child to handle the application very easily.

## 3.4 Tools and Technologies

Various tools and technologies are chosen after an analysis on the related studies in this domain. Many technologies and frameworks were analyzed to understand the pros and cons, where finally the tools and technologies which were chosen are categorized into five aspects as illustrated below.

1. **Front end framework**

React native is chosen as the front-end development framework. It is a combination of the React which is JavaScript native. This framework aids in creation of platform specific version of components which can later be shared around cross platforms too.

The main development environment used for this purpose is Visual studio code. As it is an interactive environment it supports operations such as debugging, task running and version controlling handy, all in one place.

1. **Backend framework**

The backend is completely developed using Python as the programming language along with some other python libraries such as Scikit-learn, Pandas, NumPy, Matplotlib which aids in better data analysis, preprocessing and visualization. The use of python helps easier code maintenance in few numbers of lines where object-oriented principles can be incorporated with ease.

The development environment used for the backend management is both visual studio code and PyCharm which assists proper code maintenance.

1. **Database**

Firebase database which is a real time cloud hosted storage is being used here that helps providing real time responses to the client with a seamless scalability.

1. **Facial feature analysis**

The facial features such as the AUs are analyzed and detected via Open Face [43]. Open Face is open source and is being utilized by a larger number of people in the domain of facial emotion analysis. The usage of FACS as the benchmark of the implementation is another reason for the choice.

1. **Version Control**

GitLab is used as the version control management system. The project is collaborated for continuous development and integration through this, where the issues are tracked preventing conflicts in the component development.

1. **Project management**

Throughout the entire research development, the Agile development methodology was chosen. It is an iterative approach where individual system components can be implemented in small units and integrated timely. Through this achieving the objective requirements adhering to timeline and budget constraint was possible.

At a small level within the team members, Trello boards and MS planners were maintained to track our work continuously.

1. **Application Deployment.**

The machine learning and deep learning models created are deployed as google cloud functions where inputs to the models which are videos of children playing the Chezer mobile game are stored in the S3 bucket in a concise directory structure.

# 4. RESULTS AND DISCUSSION

## Overview

The methodology as discussed in Section 2 was followed where child related video datasets were utilized in analyzing the results. A series of steps were followed in achieving the results related to the identification of AU stimulations for emotions and emotion levels along with the process of generating emotion level wise annotated data set which is further illustrated below.

### Emotion AU Stimulation Assessment.

The data prepared to assess the AU stimulations in emotions, were categorized into four basic emotions such as happy, sad, surprise and disgust where a sample of them are shown in figures 4.1.1.1 to 4.1.1.4. The categorized images for each emotion are passed to the Open face toolkit where the AU stimulations as shown in Table 4.1.1.1 are generated.

Figure 4.1.1.1 Happy EFA Sample

Figure 4.1.1.2 Sad EFA Sample

A picture containing person, hairpiece

Description automatically generated

Figure 4.1.1.3 Surprise EFA Sample

Figure 4.1.1.4 Disgust EFA Sample

Table 4.1.1.1 AU of EFA Sample

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Image | AU01\_r | AU02\_r | AU04\_r | AU05\_r | AU06\_r | AU07\_r | AU09\_r |
| 01 | 0.57 | 0.36 | 0 | 2.14 | 0.16 | 0.64 | 0.06 |
| 02 | 1.14 | 1.59 | 0.58 | 0.58 | 0 | 1.95 | 2.27 |
| 03 | 0 | 0 | 1.4 | 0 | 1.47 | 1.11 | 2.69 |

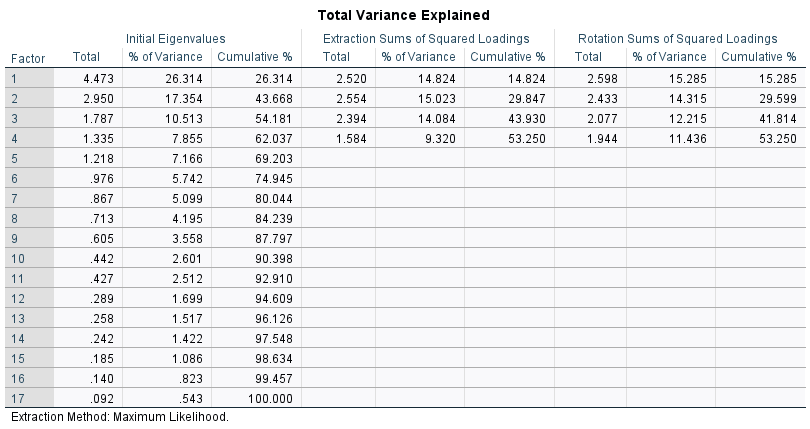
During the EFA analysis carried out, once the data suitability is tested using KMO and Bartletts test of sphericity as illustrated in Section 2, the data features are extracted into factors using Maximum likelihood extraction technique. A variance greater then 50% is obtained for four factors in the dataset as illustrated in figure 4.1.1.5.

Figure 4.1.1.5 Variance of factors

img.emfOnce the extracted data is rotated using varimax rotation, the number of factors segregated from the dataset is interpreted via the scree plot as shown in Figure 4.1.1.6. The scree plot shows the presence of factors having an eigen value > 1 and are above the point where the slope of the curve is levelling off confirming the presence of four distinct factors within the dataset.

Figure 4.1.1.6 EFA scree plot

Having the confirmation of number of factors via the scree plot, the rotated matrix reveals the AUs belonging to each of the factor and their respective factor loadings as shown in figure 4.1.1.7. As per the EFA criteria, the features with factor loadings greater than 0.4 are considered to be belonging to one factor.

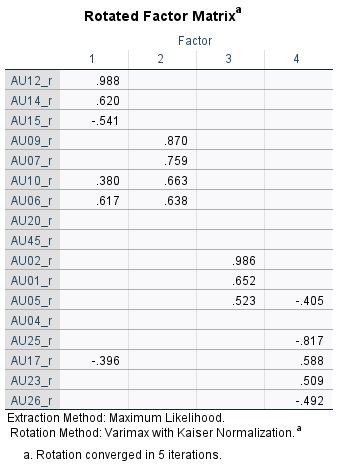


Figure 4.1.1.7 AU rotation matrix

With the observation of factors and factor loadings, four factors with the corresponding AU features are found which is illustrated below in table .

Table 4.1.1.2 Factors and Features

|  |  |
| --- | --- |
| Factor | Features |
| 01 | AU06, AU07, AU10, AU12, AU25 |
| 02 | AU01, AU04, AU15 |
| 03 | AU09, AU10, AU17 |
| 04 | AU01, AU02, AU05 |

The final step is to identify which emotion each factor represents based on the AU features included within it. Since it’s a very subjective technique and depends on the researcher, the validation here was done considering the facts proposed by the FACS as a benchmark.

Considering the factor one and the features belonging to it, the AUs correspond to facial moments such as cheek raiser, lid tightener, upper lip raiser, lip corner puller and lips part where FACS evidences that features as such belong to happy emotion expression. Thereby, factor one is labelled as happy emotion and the AUs grouped within factor one are identified to interpret happy emotion. Similarly, the factors 2, 3 and 4 are evaluated with the FACS thereby revealing the representation of emotions sad, disgust and surprise respectively. Summarized in table 4.1.1.3 are the emotions and corresponding AU facial movements identified via the EFA analysis.

Table 4.1.1.3 Factors and facial movements - EFA

|  |  |
| --- | --- |
| Factor | Features |
| Happy | Cheek raiser, lid tightener, upper lip raiser. Lip corner puller, lips part. |
| Sad | Inner brow raiser, brow lowerer, lip corner depressor. |
| Disgust | Nose wrinkler, upper lip raiser, chin raiser |
| Surprise | Inner brow raiser, outer brow raiser, upper lid raiser. |

Similar methodology followed to carry out a PCA analysis reveals, four factors and the corresponding AU features which is summarized in Table 4.1.1.4 below.

Table 4.1.1.4 Factors and facial movements - PCA

|  |  |
| --- | --- |
| Factor | Features |
| Happy | Cheek raiser, Dimpler, lips part, Lip corner puller |
| Sad | Inner brow raiser, Outer brow raiser, Upper lid raiser |
| Surprise | Lip corner puller, Lips part |
| Disgust | Nose wrinkler, upper lip raiser, lid tightener, cheek raiser. |

The EFA approach and its outcomes are further validated with the comparison of results obtained via PCA analysis.

Further comparison of the AU features activated during child emotion expressions with the AU features activated during adult emotion expression [29] provides validity that specific concern should be given on child emotion analysis rather than assuming child and adults to show similar feature activations during emotion expression. Shown below in Table 4.1.1.5 is a comparison on AU stimulations observed by EFA approach during adult and child emotion expressions.

Table 4.1.1.5 Adult and Child EFA comparison.

|  |  |  |
| --- | --- | --- |
| Emotion | Adults EFA | Children EFA |
| Happy | Cheek raiser, Upper lip raiser, Lip corner puller, Dimpler, Lips part. | Cheek raiser, lid tightener, upper lip raiser. Lip corner puller, lips part. |
| Sad | Lip corner depressor, chin raiser. | Inner brow raiser, brow lowerer, lip corner depressor. |
| Surprise | Inner brow raiser, Outer brow raiser, Upper lid raiser, Jaw drop | Inner brow raiser, outer brow raiser, upper lid raiser. |
| Disgust | Brow lowerer, Nose wrinkler | Nose wrinkler, upper lip raiser, chin raiser |

### 4.1.2 Emotion Level AU Stimulation Assessment

Having validated the AU stimulations obtained during child emotion expressions, they were further utilized in understanding their influence in child emotion levels. For this purpose, the data set prepared for emotion level assessment is utilized. A sample of data for happy emotion level assessment showing variations in emotion levels is shown in Figure 4.1.2.1

A child in a black shirt

Description automatically generated with low confidenceA child in a black shirt

Description automatically generated with low confidence

A child in a black shirt

Description automatically generated with low confidence

Figure 4.1.2.1 Sample data for Emotion level analysis.

When assessing the emotion levels, each emotion was assessed individually. The sample of images prepared with emotion level variations were passed to the Open face toolkit where the AUs were generated and assessed for the adherence of T test assumptions as illustrated in Section 2.

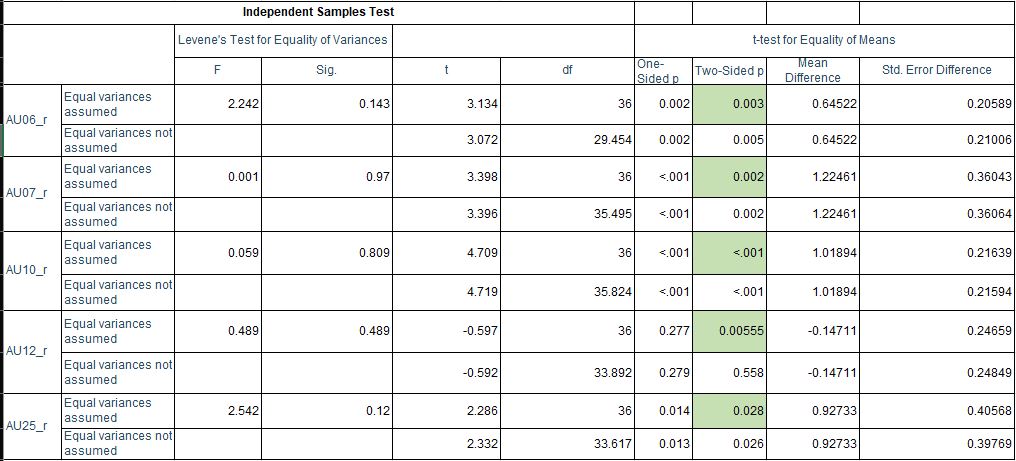
Initially the happy emotion AUs were considered for the assessment. Each AU influencing happy emotion such as 6, 7, 10, 12 and 25 were evaluated with an inferential hypothesis as illustrated in figure 4.1.2.2 below to conclude if an AU intensity changes with changing emotion levels.

Figure 4.1.2.2 Independent sample T test.

As illustrated in Figure 4.1.2.2 above, the value of two-sided p when equal variances are assumed for each AU is lesser than 0.05 significance level. Therefore, the null hypothesis is rejected which considers variances to be inequal implying that variation of intensities to be seen in all the AUs during happy emotion level changes. Similarly, the AUs stimulated during the emotion level changes of other emotions were analyzed using t test analysis. The comparison of AU stimulations obtained for emotion level changes within adults and children also justify that the solution proposed in this research is novel and highly needed where various misconceptions on handling child and adult emotion analysis as a whole should be avoided. The AU stimulations seen to influence emotion level of adult and children are compared in Table 4.1.2.1.

Table 4.1.2.1 Comparison of Emotion Level based AU between adult and children

|  |  |  |
| --- | --- | --- |
| Emotion | Adults | Children |
| Happy | 6, 10, 12, 14, 25 | 6, 7, 10, 12, 25 |
| Sad | 15, 17 | 1, 4, 15 |
| Disgust | 4, 9 | 9, 10, 17 |
| Surprise | 1, 2, 5, 26 | 1, 2, 5 |

### 4.1.3 Cluster analysis & Emotion level annotation.

As the AUs influencing emotion level of children are identified via t test analysis, they are utilized in annotating the video data with emotion levels. Once videos are split intro frames and clustered, where the AUs influencing emotion levels were passed to the K means clustering algorithm, three clusters are obtained. The manual analysis of the clusters revealed that the frames were separated into three clusters such that each cluster denotes a level of emotion expressed by children. For example, the figures 4.1.3.1 and 4.1.3.2 clearly were separated into low, moderate and high emotion level clusters respectively.

Shown below in Figure 4.1.3.1 is a cluster obtained while testing a child video with sad emotion expression. The frames of the image are segmented into three cluster where manual analysis of frames reveal that the red cluster belongs to high sad emotion expression, the green cluster to moderate sad emotion expression whereas the purple cluster denotes low sad emotion expression levels respectively.

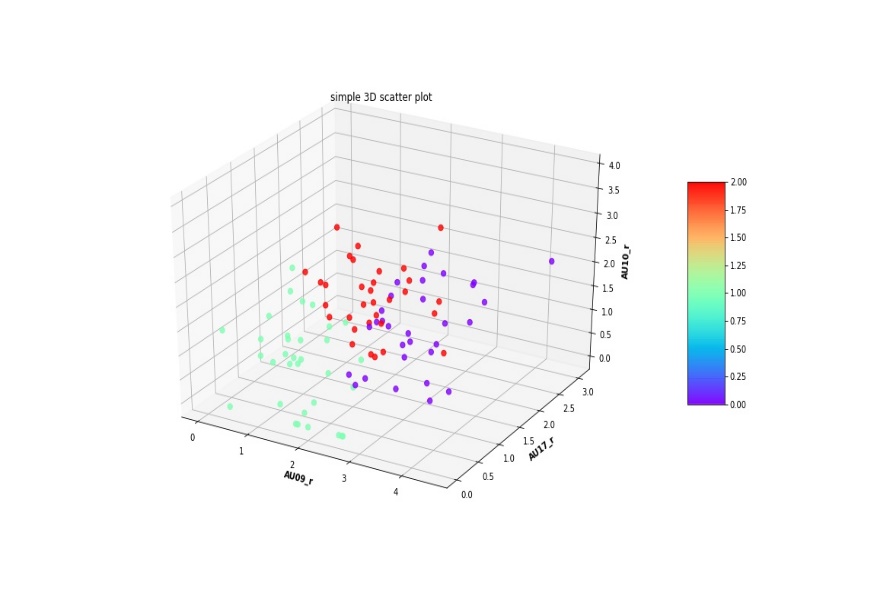


Figure 4.1.3.1 Clusters obtained for a sad emotion video.

Shown below in Figure 4.1.3.2 is a cluster obtained while testing a child video with disgust emotion expression. The frames of the image are segmented into three cluster where manual analysis of frames reveal that the red cluster belongs to high disgust emotion expression, the green cluster to moderate disgust emotion expression whereas the purple cluster denotes low disgust emotion expression levels respectively. However, the clusters also reveal slight mis categorizations at some frames of the video in which the facial features are captured in a blurry way.

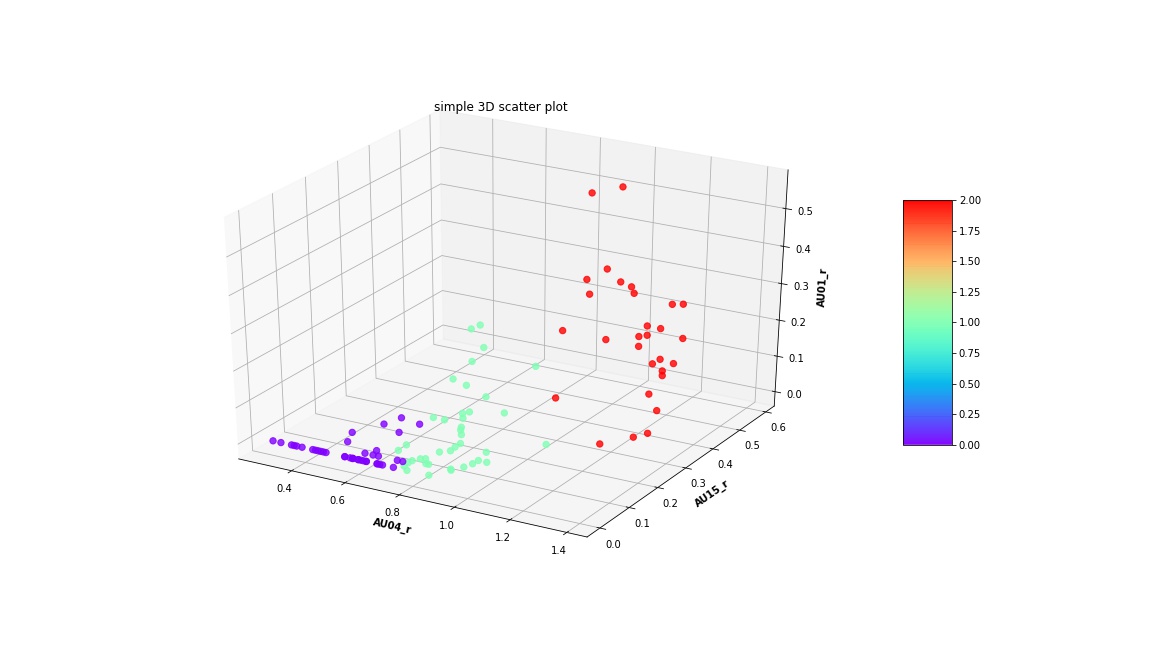


Figure 4.1.3.2 Clusters obtained for a Disgust emotion video.

Once the clusters were manually investigated for videos with all 4 emotions, annotations based on emotion levels such as high happy, moderate happy, low happy, high sad, moderate sad, low sad, high disgust, moderate disgust, low disgust, high surprise, moderate surprise, low surprise were provided to frames of video clips where finally an emotion level wise annotated dataset was prepared for model training.

### Machine learning model

Several machine learning algorithms suitable for the research problem were incorporated where the model was trained to predict the emotion level variations in video sources. Further, the parameters of the model were tuned by several techniques thereby enhancing the accuracy. In addition to test accuracy, metrics such as precision, recall, f1 score, cross validation and confusion matrix were used in assessing the performance of the model whilst concluding the most suitable model to be deployed within the application.

Shown below in table 4.1.4.1 is the comparison of accuracies obtained by incorporating three ML algorithms along with hyper parameter tuning techniques.

Table 4.1.4.1 Model accuracy comparison.

|  |  |  |
| --- | --- | --- |
| Model | Accuracy before hyper parameter tuning | Accuracy after hyper parameter tuning |
| RF | 0.8274866310160428 | 0.8686749851455733 |
| SVM | 0.8021390374331551 | 0.8191653786707882 |
| KNN | 0.8051099227569816 | 0.8068924539512775 |

Having chosen the RF model that yielded the highest accuracy after hyper parameter tuning, further assessments were done on the other model metrics.

The classification report shown below in figure 4.1.4.1 illustrates the metrics precision, recall and f1 score obtained for the RF model trained.

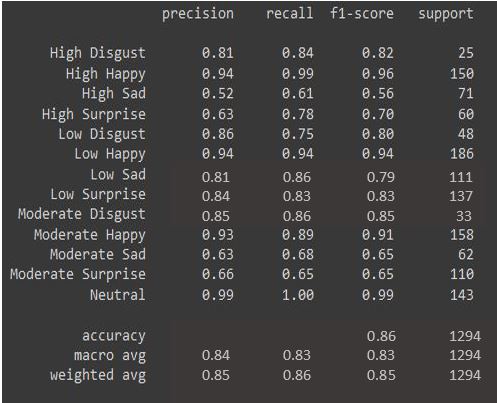


Figure 4.1.4.1 Random Forest Classification Report

1. Precision – It provides the proportions of positive identifications that were correctly identified for each class that was classified. The presence of greater precision for the 13 classes of emotion levels proves that the positive identifications through the RF model is precise.

***Precision = True Positive / (True Positive + False Positive)***

1. Recall – It provides the proportion of total relevant results classified by the algorithm. The presence of greater recall for the 13 classes of emotion levels proves that the relevance of results obtained are precise.

***Recall = True Positive / (True Positive + False Negative)***

1. F1 score – It is the mean of precision and recall. The presence of greater f1 score for all the 13 classes of emotion levels proves that the results obtained via the model is precise.

***F1 score = 2 \* (Precision \* Recall) / (Precision + Recall)***

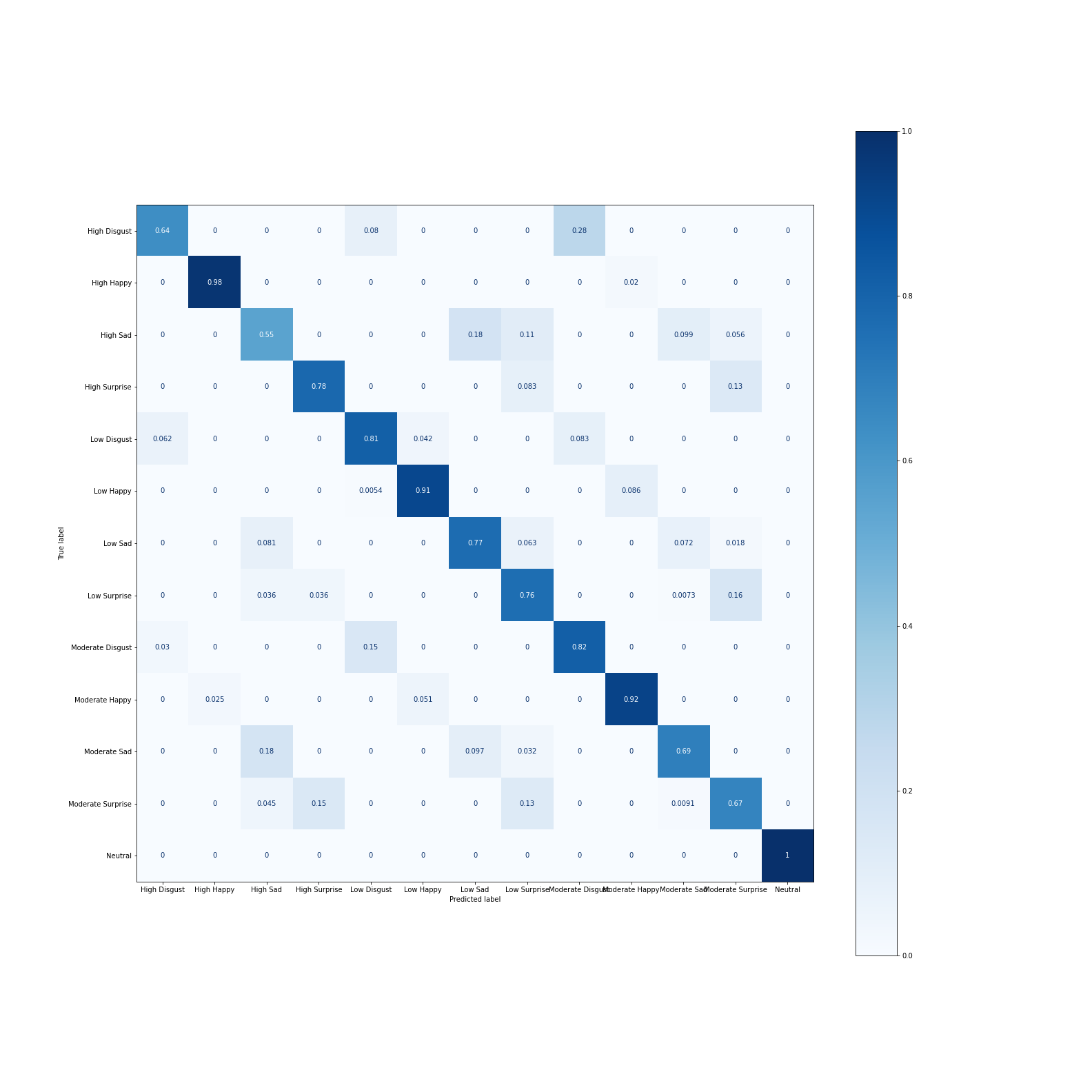
In addition to the above metrics, the analysis of confusion matrix as shown below in figure 4.1.4.2 shows how well the 13 emotion level classes were predicted through the RF classifier algorithm. There exists a few misclassifications within the same emotion, but no misclassifications are obtained among different emotions.

Figure 4.1.4.2 Random Forest confusion matrix

### Age wise analysis

As illustrated in Section 2, a similar methodology was utilized in analyzing the impact of age in children for emotion level variations. The results provide evidence that the variation of age has different muscle movement activations causing variations of emotion level expressions from one age group to another. The age groups majorly considered are 4 – 6 years and 6 – 10 years.

Illustrated below in table… are the action unit stimulations of emotion levels seen in the two age groups as a result of an EFA analysis followed by an independent sample t test.

Table 4.1.5.1 Age wise Emotion level Au stimulations.

|  |  |  |
| --- | --- | --- |
| Emotion | 4-6 Years | 6-10 Years |
| Happy | AU6 and AU12 | AU06, **AU14**, AU12, **AU10** |
| Sad | AU17 and **AU23** | **AU15,** AU17, **AU4** |
| Surprise | **AU1**, AU2, **AU5** | AU2, **AU25**, **AU26** |
| Disgust | AU9, **AU10** | **AU6, AU7,** AU9, **AU23** |

It is seen that the AU muscle activations vary from one age group to another and not all muscles are similarly stimulated with varying emotion level stimulations in children belonging to different age groups.

Utilizing the action units identified via the EFA and t test analysis, the datasets prepared for an age wise analysis were clustered by the K means clustering algorithm. The algorithm revealed distinct clusters where, by manual analysis it was verified to be separated based on emotion levels high, moderate, and low. Shown below in figure 4.1.5.1 are the clusters obtained for the emotions happy and disgust in age group 4-6.

Chart, radar chart

Description automatically generatedChart

Description automatically generated

1. *Disgust Emotion cluster*
2. *Happy Emotion cluster*

Figure 4.1.5.1 Age 4-6 Emotion Level Clusters

Once the clusters obtained as above are manually verified, the dataset prepared with variations of age group are annotated with emotion level variations thereby a machine learning classifier is built. Several machine learning algorithms appropriate to the problem is utilized here where RF yields the highest accuracy among them. Further the parameters of the model were tuned via grid search cv technique thereby improving the accuracy as illustrated in Table 4.1.5.2 below.

Table 4.1.5.2 Model accuracy comparison with age variations.

|  |  |  |
| --- | --- | --- |
| Model | 4-6 Years | 6-10 Years |
| RF | 0.896242774566474 | 0.8427058823529412 |
| SVM | 0.7696447793326158 | 0.7995927973126238 |
| KNN | 0.7631862217438106 | 0.7745698473326310 |

Shown below in Figure 4.1.5.2 is the classification report belonging to age group 4-6 illustrating metrics such as precision, recall and f1 score.

![Table, calendar

Description automatically generated with medium confidence](data:image/jpeg;base64,/9j/4AAQSkZJRgABAQEAYABgAAD/4RDcRXhpZgAATU0AKgAAAAgABAE7AAIAAAAGAAAISodpAAQAAAABAAAIUJydAAEAAAAMAAAQyOocAAcAAAgMAAAAPgAAAAAc6gAAAAgAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAEtvdmkhAAAFkAMAAgAAABQAABCekAQAAgAAABQAABCykpEAAgAAAAM3MwAAkpIAAgAAAAM3MwAA6hwABwAACAwAAAiSAAAAABzqAAAACAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA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Figure 4.1.5.2 Age 4-6 RF Classification Report.

In addition to the above metrics, the analysis of confusion matrix as shown below in figure 4.1.5.3 shows how well the 13 emotion level classes were predicted through the RF classifier algorithm. There exists a few misclassifications within the same emotion, but no misclassifications are obtained among different emotions.

Chart, scatter chart

Description automatically generated

Figure 4.1.5.3 Age 4-6 RF Confusion Matrix

## Research Findings

DATA AUGMENTATION CANNOT BE USED BCZ OF OPEN FACE

THE MUSCULAR MOVEMENTS DIFFERENT BETWEEN ADULTS AND CHILDREN

THEY IMPROVE WITH AGE

## Discussion

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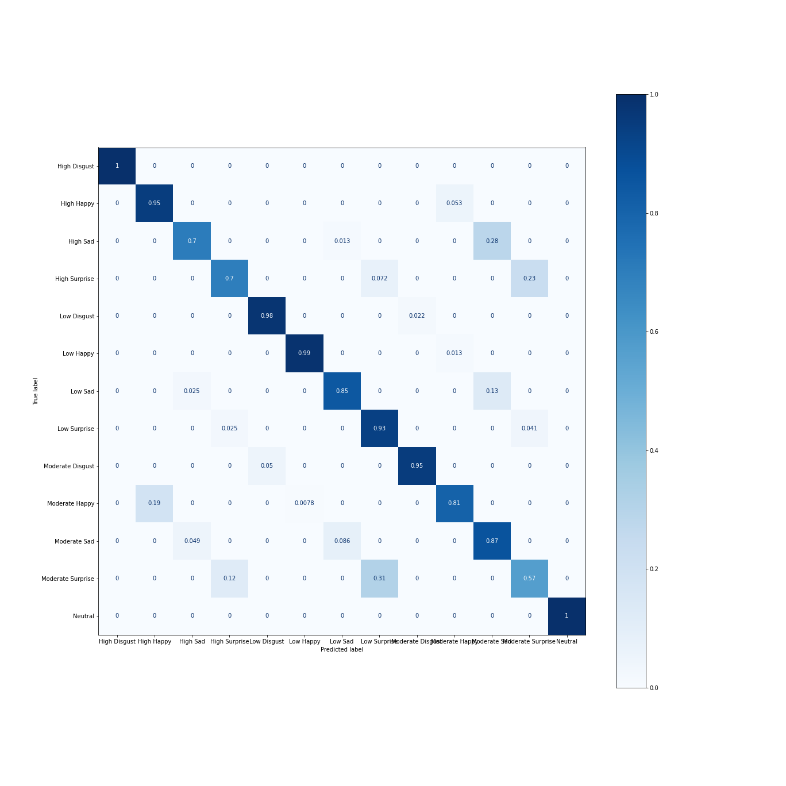
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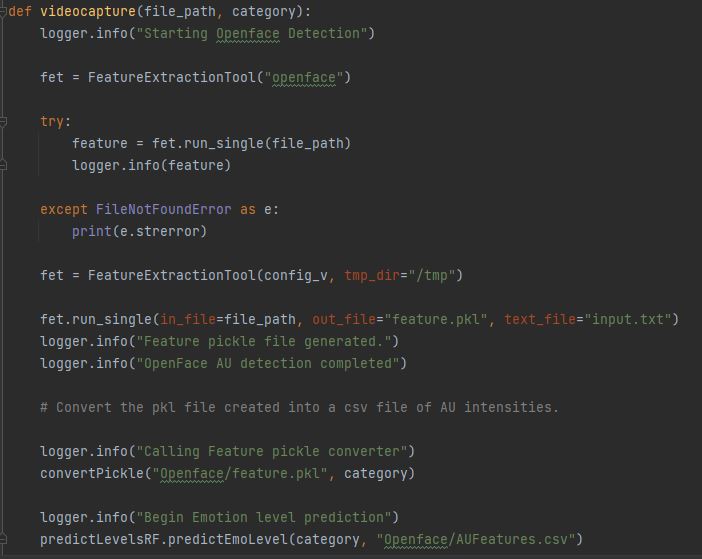
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# Calendar Description automatically generatedAPPENDICES

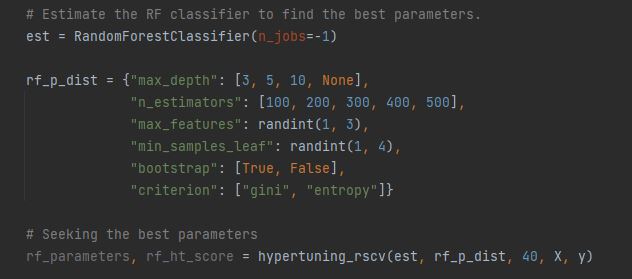
Appendix 1 Age 6-10 Confusion Matrix

Appendix 2 : Age 6-10 Classification Report





Appendix 3 Open Face Python Implementation



Appendix 4 Hyper parameter tuning - Gridsearch CV