FACIAL BLENDSHAPE PERCEPTION STUDIES FOR MOTION CAPTURE AND INTEGRATION WITH INTERACTIVE MEDIA

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This Report Presented in Partial Fulfillment of the Requirements for the Degree of Bachelor of Science in Multimedia and Creative Technology

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APPROVAL

This Project titled "**Facial Blendshape Studies for Motion Capture and Integration with Interactive Media**", submitted by Shykh Anjum to the Department of Multimedia and Creative Technology, Daffodil International University, has been accepted as satisfactory for the partial fulfillment of the requirements for the degree of B.Sc. in Multimedia and Creative Technology and approved as to its style and contents. The presentation has been held on 04 March, 2023.
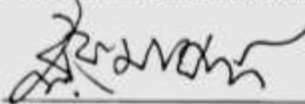
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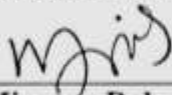**Assistant Professor & Head (In-Charge)**

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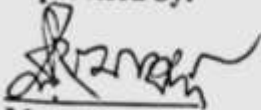
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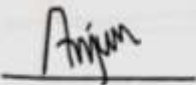
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ii

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ABSTRACT

This research paper investigates the perception of BlendShapes through Action Unit activation by Bangladeshi individuals. The study aims to identify the level of understanding and recognition of BlendShapes, which are commonly used in the animation and gaming industry for facial expression and emotion representation. To achieve this, participants are presented with a series of facial expressions created using BlendShapes and asked to identify the emotion being portrayed. Furthermore, a real-time facial capture setup is designed using these BlendShapes to capture facial expressions and emotions in real-time. The study provides insights into the perception of facial expressions by Bangladeshi individuals and the potential applications of BlendShapes in creating realistic digital avatars. The findings of this research could be useful in various fields, such as computer graphics, virtual reality, and gaming industries, where realistic facial expressions and emotions are crucial for creating engaging experiences.

TABLE OF CONTENTS

CONTENTS	PAGE

LIST OF FIGURES

FIGURES	PAGE

LIST OF TABLES

GLOSSARY

TERM	**DEFINITION**
BlendShapes	Transforming the target object shapes into a blend of the base object shapes.
Activation Level	Intensity of changes in Blendshape
ANOVA	Analysis of variance, statistical technique for dividing observed variance data into its various components.
	SS-Sum of Squares; df- degree of Freedom; MS- Mean Square; F-ratio of two variances; P value- significant factors; F crit- Critical value of F
AU	The basic operations of a muscle or group of muscles that ultimately creates expressions
Digital Human	A virtual avatar capable of displaying a wide variety of human body language
Edgeflow	Making sure that edges conform to the model's geometry and curvature
FACS	Facial Action Coding System, a system to classify human facial motions according to how they appear on the face
Hierarchy	The way GameObjects are sorted in respect to their relations in a scene of a game engine.
Motion Capture	Process of recording live-objects movement.
Retopology	Modeling procedure where the polygonal mesh of an item is changed or reconstructed to produce a cleaner structure.

Chapter 1

INTRODUCTION

1.1 Introduction

The term "Metaverse" has become one of the most popular buzzwords in recent years. Although the idea of a virtual world is nothing new, it has lately gained popularity as a result of the advancement of VR technology. What, though, is the "Metaverse" in reality? It appears to be a preferred name-dropping among businesses like Facebook, Google, and NVIDIA. The actual technology behind the metaverse, however, and the things that are conceivable with it, are considerably more competent than what these billion-dollar businesses are letting on at the moment. A truly virtual environment must be able to recognize and depict human emotions in real time rather than merely allowing some low-poly game characters to just walk around. Because in a world where we are unable to communicate via our facial emotions, our human brains will never fully emerge.

Face perception is a particularly active topic of research in psychology since it has been demonstrated that people view faces differently than other objects [3] According to research by Schwaninger et al., rather than being processed holistically, faces are also analyzed in terms of their individual parts and how they are arranged [8]. Emotion is a major psychological component that influences facial expressions. Emotions are internal states associated with physiological arousal and behavioral changes, such as changes in facial expressions. When a person is pleased, they may grin, and when they are upset, they may frown. These facial expressions are regarded to be universal and are often recognized by people from all cultures. Cognition, or the processes of thinking and reasoning, is another major psychological aspect underlying facial expressions. Even when we are not consciously aware of it, our ideas and beliefs can impact the facial expressions we create. For example, if a person is thinking about something that makes them happy, they may involuntarily grin without realizing it. In general, the psychological explanations for facial expressions are intricate and multifaceted, and they may involve emotions, ideas, and cultural context. These variables can affect how people express themselves facially, as well as how they are affected by others' emotions.

1

There were further studies that employed information about individual action units to construct synthetic phrases. The detection of an expression was achieved by gradually activating certain action units [11]. Reverse engineering expressions based on perceptual relevance aided in enhanced facial recognition in artificial faces.[2] There is ample data to demonstrate that action units alone have a perceptually substantial influence on emotion classification. However, it is uncertain if certain action units are more noticeable than others because they are connected with a specific emotional expression.

The idea is to provide people access to real-time face capturing technology. Real-time face tracking was previously impossible, despite the fact that face tracking technology is utilized in movies like The Lord of the Rings, Pirates of the Caribbean, and Avatar. This has changed because of the incredible advancements in GPU technology. Any character may be made to come to life in real time utilizing Apple's ARKit or a comparable face tracking program with the necessary BlendShapes data. Any spectrum of human emotions may be simulated using those BlendShapes data, which can be then sent to a game engine like Unity, Unreal or in any virtual reality platform like the Metaverse.

Live face capture is a method used in the creation of movies and video games to record the movements and facial expressions of actors in real-time. This makes it possible to create character animations that are incredibly precise and lifelike, especially when it comes to their facial emotions. In order to follow the actor's facial movements and expressions during live face capture, sophisticated tools like depth sensors and infrared cameras are frequently used. The actor's performance may then be instantly transferred into the virtual environment using this data, which is then utilized to drive the animation of the digital character in real time. However, such technology is expensive and necessitates a plethora of specialized devices and software that are out of reach for the mainstream population. This is where predetermined facial-BlendShapes and Action Unit (AU) come in, which can track a human face's movement using LIDAR technology and replicate almost the same outcome.

In this paper, I'll explore the possibility of employing BlendShapes (morph targets) to record real-time face expression and establish a standard for affordable character facial

2

animation that can be used in any virtual environment. The motivation behind that is to establish a standard derivation in BlendShapes perception for Digital humans in Bangladesh.

Chapter 2
REVIEW OF RELATED LITERATURE

2.1 Modeling a Face for Facial Animation

The first step in preparing any character for facial animation is to accurately model the face. By accurately, I mean modeling the face in a way that allows the face to be rigged to follow the natural movement of a human face. Edgeflow is a critical component that must be maintained in order to do this, because it determines how smoothly and naturally the surface of the face will deform when the model is animated. Edgeflow refers to the way that the edges of the polygons in a 3D model are arranged and connected to each other. A model with good Edgeflow will have edges that follow the natural contours and wrinkles of the face, allowing the model to deform smoothly and naturally when it is animated. This is important because it helps to create a more realistic and expressive animation. On the other hand, a model with poor Edgeflow may have edges that do not follow the natural contours of the face, resulting in unnatural or distorted deformations when the model is animated. This can lead to a less realistic and less expressive animation.

In the book *Stop Staring: Facial Modeling and Animation Done Right* the author Jason Osipa describes the ideal way to model a face and its facial features to be ready for animation. He described the lip sync part as -

"When teased apart properly, the lip sync portion of facial animation is the easiest to understand because it's the simplest. You see, people's mouths don't do that much during speech. Things like smiles and frowns and all sorts of neat gooey faces are cool, and we'll get to them later, but for now we're just talking sync. Plain old speech. Deadpan and emotionless and, well, boring, is where our base will be. Now, you're probably thinking, "Hey! My face can do all sorts of stuff! I don't want to create boring animation!" Well, you're right on both counts: Your face can do all sorts of things, and who really wants to do boring animation? Nobody! For the basics, however, this is a case of learning to walk before you can run. For now, we're not going to complicate it. If we jumped right into a world with hundreds or even thousands of verbal and

4

emotional poses (which is how they do it in the movies), we'd never get anywhere. So, to make sure you're ready for the advanced hands-on work later, we're focusing on the most basic concept now: bare-bones lip sync. When dealing with the essentials of lip sync and studying people, there are just two basic motions. The mouth goes Open/Closed, and it goes Wide/Narrow, as illustrated in below figure. [7]

Figure 2.1 A human mouth in the four basic poses

2.2 Face Modelling and Edgeflow

Edgeflow is an important consideration in face modeling because it affects the overall quality and realism of the model. Edgeflow refers to the way that the edges of a 3D model are arranged and connected, and it plays a role in how the model deforms and moves during animation.

Figure 2.2.1 Proper Edgeflow of the face by artist Miguel Miranda

Good edgeflow is important for a number of reasons:

1. Smooth deformation: Good edgeflow helps to ensure that the mesh deforms smoothly when it is animated, which is particularly important for facial animation. This can help to create more realistic and expressive facial movements.

2. Efficient topology: Good Edgeflow can help to make the topology of the mesh more efficient, which can make it easier to work with and can reduce the risk of errors or problems during the modeling process.

3. Better shading: Good Edgeflow can help to ensure that the shading of the mesh is smooth and consistent, which can improve the overall appearance of the model.

When a model is animated, good Edgeflow ensures that it deforms smoothly and naturally without causing unwanted artifacts such as pinching or stretching. This is critical for facial animation since the face is one of the body's most expressive and dynamic organs, and viewers can detect even tiny variations.

Figure 2.2.2 Planning the Facial Retopology by Julien Kaspar [5]

To achieve good Edgeflow in a face model, it is important to carefully plan the placement and connectivity of the edges, taking into account the movements and deformations that the model will need to perform. This may involve adding or removing edges, or adjusting the placement of existing edges.
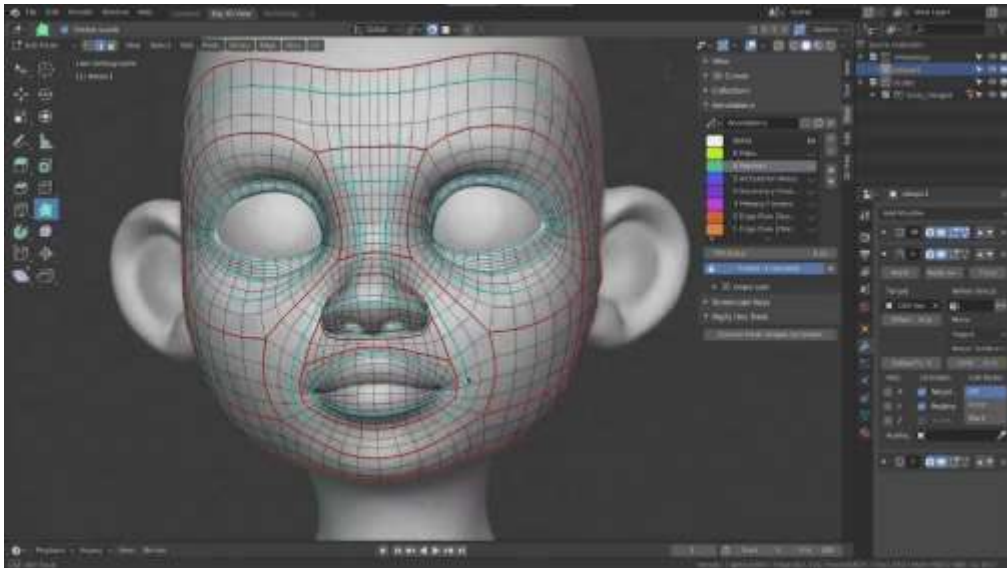
Figure 2.2.3 Facial Retopology by Julien Kaspar (Blender Studio)

Edgeflow is a significant concern in face modeling since it has a large impact on the final model's quality and realism. We can see a proper Edgeflow in figure 2.2.3 by artist Julien Kaspar.[5]

2.3 Facial BlendShapes

Blendshapes, also known as morph targets or mesh deformation, are a 3D computer graphics technique for making tiny changes to the shape of a mesh. This enables a more fluid transition between forms, resulting in more realistic and fluid animations. This method is used in 3D computer graphics to generate smooth and seamless transitions between different face expressions or forms. It's widely utilized in animation and film production to generate realistic and accurate character motions, especially for face expressions. In the research paper "Practice and Theory of Blendshape Facial Models", we get the definition:

Blendshapes are linear facial models in which the individual basis vectors are not orthogonal but instead represent individual facial expressions. The individual basis vectors have been referred to as blendshape targets and morph targets, or (confusingly) as shapes or blendshapes. The corresponding weights are often called sliders, since this is how they appear in the user interface [6]

To create a BlendShape animation, the artist first selects the rest pose mesh and sets it as the base for the animation. They then create the various targets that they want to use in the animation. Each target is created by making small changes to the vertices of the mesh, either by moving them manually or using a sculpting tool. Once the targets have been created, the artist can then use them to animate the mesh. This is done by blending the different targets together, using a value known as the "blend weight" to control the amount of each target that is used in the final shape of the mesh. By adjusting the blend weights over time, the artist can create smooth transitions between different shapes, resulting in realistic and fluid animations.

9

Figure 2.3.1 Examples of Blendshapes

BlendShapes have become an essential tool in the world of 3D animation, allowing artists to create more realistic and expressive characters. They are widely used in a variety of applications, including video games, movies, and television shows. Because BlendShapes are based on small changes to the rest pose mesh, they can be easily modified and adjusted to create a wide range of shapes and animations.

Figure 2.3.2 Screenshot of a portion of the blendshape slider interface

2.4 Facial Action Coding System & Action Units

The Facial Action Coding System (FACS) is a collection of facial muscle movements that correspond to the expression of an emotion. Carl-Herman Hjortsjö invented it in 1970 with 23 facial motion units, and Paul Ekman and Wallace Friesen improved on it. The FACS was initially published in 1978, however it was significantly revised in 2002.

Table1: Table of Action Units and related Muscles.

Action Unit	Description	Facial Muscle
1	Inner Brow Raiser	*Frontalis, pars medialis*
2	Outer Brow Raiser (	*Frontalis, pars lateralis*
4	Brow Lowerer	*Depressor Glabellae, Depressor Supercilli, Currugator*
5	Upper Lid Raiser	*Levator palpebrae superioris*
6	Cheek Raiser	*Orbicularis oculi, pars orbitalis*
7	Lid Tightener	*Orbicularis oculi, pars palpebralis*
9	Nose Wrinkler	*Levator labii superioris alaeque nasi*
10	Upper Lip Raiser	*Levator Labii Superioris, Caput infraorbitalis*
11	Nasolabial Deepener	*Zygomatic Minor*
12	Lip Corner Puller	*Zygomatic Major*
13	Cheek Puffer	*Levator anguli oris (Caninus)*

Action Unit	Description	Facial Muscle
14	Dimpler	*Buccinator*
15	Lip Corner Depressor	*Depressor anguli oris (Triangularis)*
16 (with AU25)	Lower Lip Depressor	*Depressor labii inferioris*
17	Chin Raiser	*Mentalis*
18	Lip Puckerer	*Incisivii labii superioris* and *Incisivii labii inferioris*
20	Lip stretcher	*Risorius *
22	Lip Funneler	*Orbicularis oris*
23	Lip Tightener	*Orbicularis oris*
24	Lip Pressor	*Orbicularis oris*
25	Lips part	*Depressor Labii, Relaxation of Mentalis (AU17), Orbicularis Oris*
26	Jaw Drop	*Masetter; Temporal and Internal Pterygoid *relaxed
27	Mouth Stretch	*Pterygoids, Digastric*
28	Lip Suck	*Orbicularis oris*
41	Lid droop	Relaxation of *Levator Palpebrae Superioris*
42	Slit	*Orbicularis oculi*
43	Eyes Closed	Relaxation of *Levator Palpebrae Superioris*
44	Squint	*Orbicularis oculi, pars palpebralis*

Action Unit	Description	Facial Muscle
45	Blink	*Relaxation of *Levator Palpebrae and Contraction of Orbicularis Oculi, Pars Palpebralis. **
46	Wink	*Levator palpebrae superioris; Orbicularis oculi, pars palpebralis*

2.5 Facial Expressions

Author Uldis Zarins provided a thorough explanation of facial anatomy in his book *Anatomy of Facial Expressions* [12], highlighting the connections between the muscles in our faces that are located beneath the skin. As you can see, the muscles in our face are all interrelated, making it difficult to move one muscle without also moving others.

Figure 2.5.1 Facial expressions beneath skin

The system is based on the idea that specific facial muscles produce specific facial movements, and that these movements can be used to identify emotions or other internal states. The movements are organized into a set of action units (AUs), which are numbered and defined according to the specific muscles and movements involved. For example, AU 1 corresponds to inner brow raise, AU 2 corresponds to outer brow raise, and so on.

Figure 2.5.2 Facial expression: Fear

Figure 2.5.3 Facial Expression: Fear

2.6 Facial Motion Capture in Industry

FACS has been widely used in research on facial expression and emotion, and it has also been used as a tool for creating realistic facial animations in film and video games. In live face tracking, FACS can be used to analyze and interpret real-time facial movements in order to generate corresponding facial animations or to identify emotions or other internal states.

2.6.1 Facial Motion Capture in Films

The character Gollum in the Lord of the Rings trilogy is one example of how face tracking has been used in cinema. Andy Serkis played Gollum in the movie utilizing motion capture, with his facial emotions recorded using a number of techniques, including face tracking. The resultant facial movements were then utilized to produce Gollum's computer character model, from which the final character animation in the movie was generated.

Figure 2.6.1.1 Andy Serkis as Gollum in The Lord of the Rings (2001)

Facial tracking has been employed in a number of big motion pictures to produce realistic facial animations for human and non-human creatures. Other films that have incorporated face tracking include The Hobbit series, Avatar, The Avengers, The Pirates of the Caribbean series, and The Planet of the Apes series. Facial tracking was

18

utilized in these films to produce accurate facial animations for both human and non-human characters, as well as digital doubles of performers for use in character animation.

Figure 2.6.1.2 Zoe Saldana as Neytiri in Avatar 1 (2009)

Figure 2.6.1.3 Benedict Cumberbatch as Smaug in The Hobbit (2013)

Figure 2.6.1.4 Andy Serkis and Jason Clarke as Caesar and Malcolm in Dawn of the Planet of the Apes (2014)

Figure 2.6.1.v Josh Brolin as Thanos in Avenger Endgame (2019)

Avatar 2 by James Cameron introduces a new technology that replaces the FACS system with the Anatomically Plausible Facial System, or APFS. "A FACS system simply simulates an external face and has extremely limited capabilities... It is only an

20

emotional mechanism that codes expressions. FACS does not encode communication, yet much of what we do is dialogue." While FACS may accurately capture an isolated emotion, there is no information on how to transition between poses. "You end up having to sort of guess," reveals Joe Letteri, Avatar's VFX director and four-time Oscar winner. [9]

Figure 2.6.1.vi Sam Worthington and Zoe Saldana as Jake Sully and Neytiri in Avatar the Way of Water (2022)

2.6.2 Facial Motion Capture in Games

The Ninja Theory team created a facial scan of Melina Juergens, the actress who portrays Senua, the main character in the video game Hellblade: Senua's Sacrifice, using photogrammetry, a technique for determining depth from images. In order to track the actor's face and bodily movements as well as the filmer's position in 3D space, the team later developed Hydra, a prototype camera system with several GoPros and replaceable lenses. A camera and a cricket helmet were used in another prototype to record faces. The characters BlendShapes then received this information using the Unreal engine.

To describe how experimental the technology still is, Ninja Theory's Chief Creative Director Tameem Antoniades said, "It was just unproven at the time, and we were the guinea pigs. But it worked beautifully. The detail was just incredible." [10]

Figure 2.6.2 Senua hellblade

2.6.3 Facial Motion Capture in Online Platforms

A live face tracking Vtuber is a virtual character that uses real-time facial tracking to generate facial animations in response to the movements and expressions of a human performer. The process typically works as follows:

1. The performer wears a headset with a camera or other sensor that is used to capture their facial movements and expressions.

2. The camera or sensor feeds live video of the performer's face to a computer running facial tracking software.

3. The facial tracking software analyzes the movements and expressions of the performer's face in real time, and generates corresponding facial animations for the Vtuber character.

4. The facial animations are combined with a 3D model of the Vtuber character and rendered in real time, creating a live video feed of the Vtuber character with facial movements that match those of the performer.

5. The live video feed of the Vtuber character is then streamed online, allowing viewers to watch and interact with the character in real time.

Figure 2.6.3.1 CodeMiko

The twitch streamer CodeMiko is one of the most well-known Vtubers that uses facial tracking for her virtual avatar. She is among the first persons to use online streaming services in this manner. The unique aspect of CodeMiko is that her creation utilizing the Unreal engine, as well as her interactions with other people, are becoming mainstream and no longer feel strange. CodeMiko is a pioneer in the virtual representation in this sector, whether it be VTube, VRChat, or the Metaverse. Youna Kang, the person behind CodeMiko's both technical and real-life selves, addressed Inverse Magazine about the challenges she faces, saying, "wearing everything was the hardest part, because I would feel like I was being strangled in my suit a lot. If you stream for six hours every single day, the trackers keep hitting the same pressure points. Those trackers would actually start hurting my skin, which becomes really uncomfortable."

Figure 2.6.3.2 CodeMiko Facial Expression

2.7 Psychological Factors Behind Different Facial Expressions

Fasel & Luettin stated that the causes of facial expressions include mental states (e.g., felt emotions, conviction, and cogitation), verbal communication (e.g., illustrators, listener reactions, and regulators), nonverbal communication (e.g., unfelt emotions, emblems, and social winks), and physiological processes (e.g., manipulators, pain and tiredness). As seen in Figure 2.7, we divide the elements that determine face expressions into social, emotional, and physiological components, as well as expressive personality. [4]
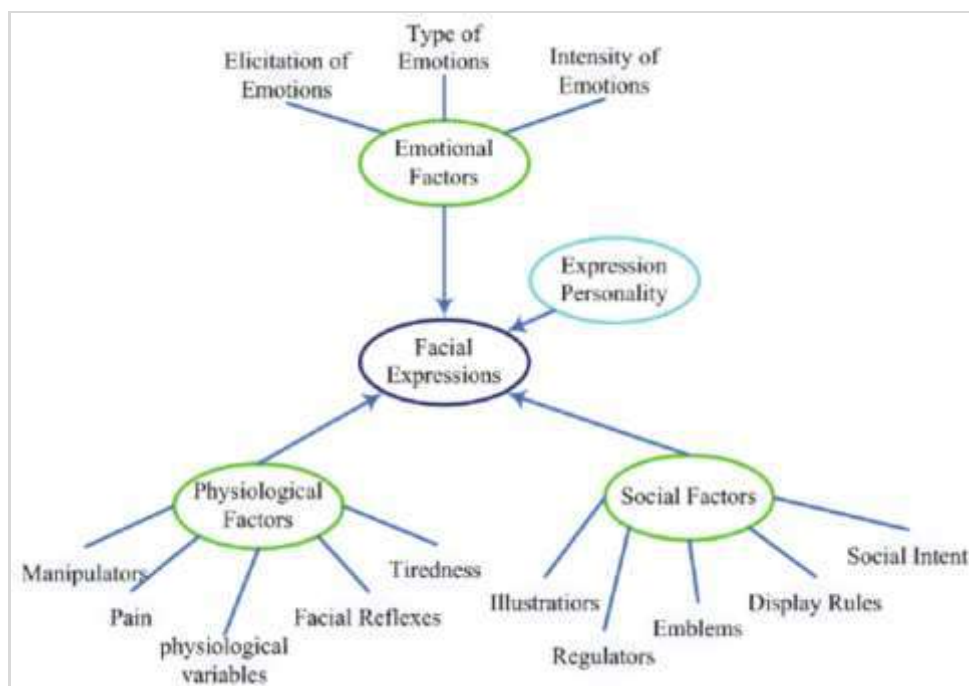
Figure 2.7 Factors that influence facial expressions

Thus, it is evident that no matter how skilled an animator is, they will never be able to precisely duplicate the intricacy of expression and feeling. Facial Motion Capture is therefore extremely important in the virtual reality environment in order to communicate emotion.

Chapter 3

BLENDSHAPE PERCEPTION ANALYSIS

This chapter is heavily influenced by research done in Trinity College Dublin, which was published in the 13th ACM SIGGRAPH Conference in 2020. The research paper is titled *Investigating perceptually based models to predict importance of facial BlendShapes* [1] The researchers chose a neutral face and 9 BlendShapes to better understand the perception of the viewers of digital humans. They wanted to see which activation level is appropriate for which Action Units. In the original research, the researcher took 20 participants and showed them the chosen Action Units in various activation levels, and the participants had to choose the AU they perceive to be truly able to convey the said Emotion. The participants were predominantly White and of European ethnicity. I re-examined the same AU perception experiment but with Bangladeshi Participants. Here are the 9 AUs that were selected:

AUs which are important for emotion:

AU 2: Right Eyebrow Up (Outer Brow Raiser)

AU 4: Frown (Brow Lowerer)

AU 5: Eye Open (Upper Lid Raiser)

AU 12: Smile (Lip Corner Puller)

AU 15: Mouth Frown (Lip Corner Depressor)

AU 38: Nostril Dilator

AUs which are important for speech:

AU 18: Lip Pucker

AU 34: Cheeks Puffed

AU 26: Jaw Drop

A neutral Face was shown to all participants, with 5 activation levels of 0.2, 0.4, 0.6, 0.8, and 1.0 for each of them, where 0.2 being the lowest activation and 1.0 being the highest activation.

3.1 Survey of Perceptual Analysis

I have conducted an online survey where 54 participants participated and answered the survey questions. I had put two variables while conducting the survey, a*ge* and *gender*. The motivation of this survey is to replicate the original research as closely as possible. But as this participant pool only consists of 1 race, the variable race is omitted. All the options were randomized, so that participants don't get biased.
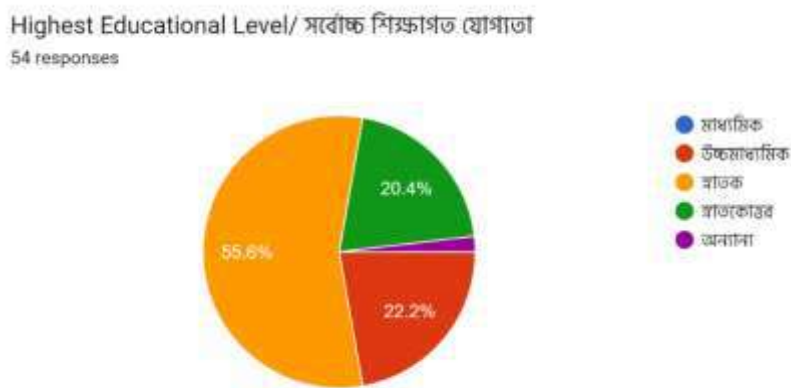
Figure 3.1.1 Percentage of Highest Education Level of Participants
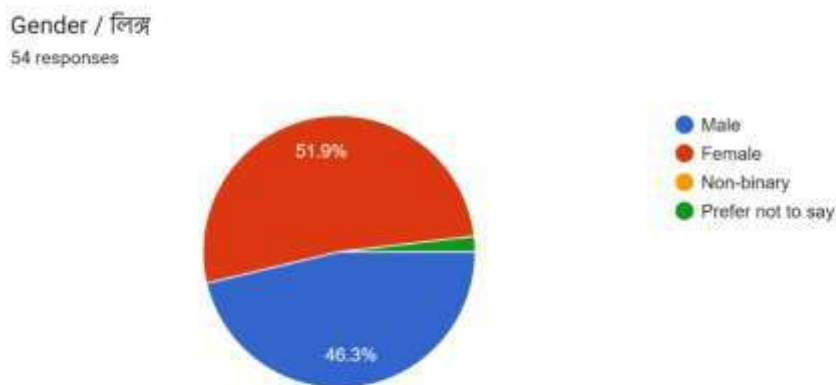
Figure 3.1.2 Percentage of Gender Dividation of Participants

Age/ বয়স
54 responses

● ৮৫-২৫
● ২৬-৩৫
● ৩৬-৫০
● ৫০+

44.4%

55.6%
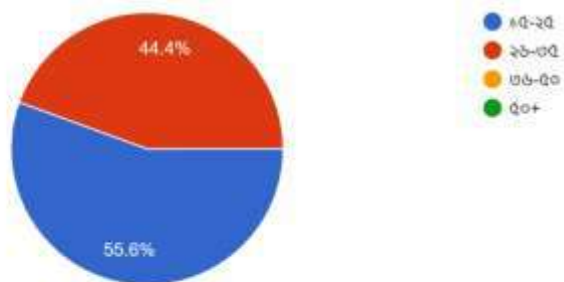
Figure 3.1.3 Age Group

AR/VR এবং Metaverse এর মতো virtual reality platform এর সাথে আপনার পরিচিতি আছে?
54 responses
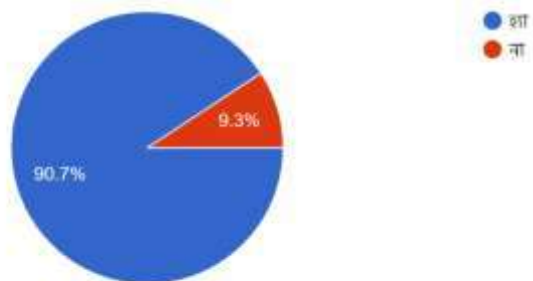
● হ্যা
● না

9.3%

90.7%

Figure 3.1.4 Familiarity with VR platforms

28

Figure 3.1.5 Neutral Face

The Neutral Face is the one that was determined as a face with no apparent expression. All the AU has to be compared with this face.

AU 2: Right Eyebrow Up:

Right Eyebrow Up (ডান ভ্রু উচানো) *

Figure 3.1.6 AU 2: Right Eyebrow Up (Outer Brow Raiser)

Option 1-   0.4
Option 2-   0.2
Option 3-   0.6
Option 4-   1.0
Option 5-   0.8

Survey Result:

Figure 3.1.7 Percentage of AU activation level

Figure 3.1.8 Percentage of AU activation level: Male - Female ratio

AU 4: Frown (Brow Lowerer)

Frown (কঠোর চাহনি) *

Figure 3.1.9 AU 4: Frown (Brow Lowerer)

Option 1-   0.6
Option 2-   1.0
Option 3-   0.8
Option 4-   0.2
Option 5-   0.4

Survey Result:

Figure 3.1.10 Percentage of AU activation level

Figure 3.1.11 Percentage of AU activation level: Male - Female ratio

AU 5: Eye Open

Eye Open (চোখ খোলা) *

Figure 3.1.12 AU 5: Eye Open (Upper Lid Raiser)

Option 1-	0.2
Option 2-	0.4
Option 3-	0.6
Option 4-	1.0
Option 5-	0.8

Survey Result:

Figure 3.1.13 Percentage of AU activation level

Figure 3.1.14 Percentage of AU activation level: Male - Female ratio

AU 12: Smile

Smile (হাসি) *

Figure 3.1.15 AU 12: Smile (Lip Corner Puller)

Option 1-	1.0
Option 2-	0.2
Option 3-	0.6
Option 4-	0.4
Option 5-	0.8

36

Survey Result:

Figure 3.1.16 Percentage of AU activation level

Figure 3.1.17 Percentage of AU activation level: Male - Female ratio

AU 15: Mouth Frown

Mouth Frown (বিরাগ) *

Figure 3.1.18 AU 15: Mouth Frown (Lip Corner Depressor)

Option 1-   0.2
Option 2-   0.4
Option 3-   0.6
Option 4-   0.8
Option 5-   1.0

Survey Result:
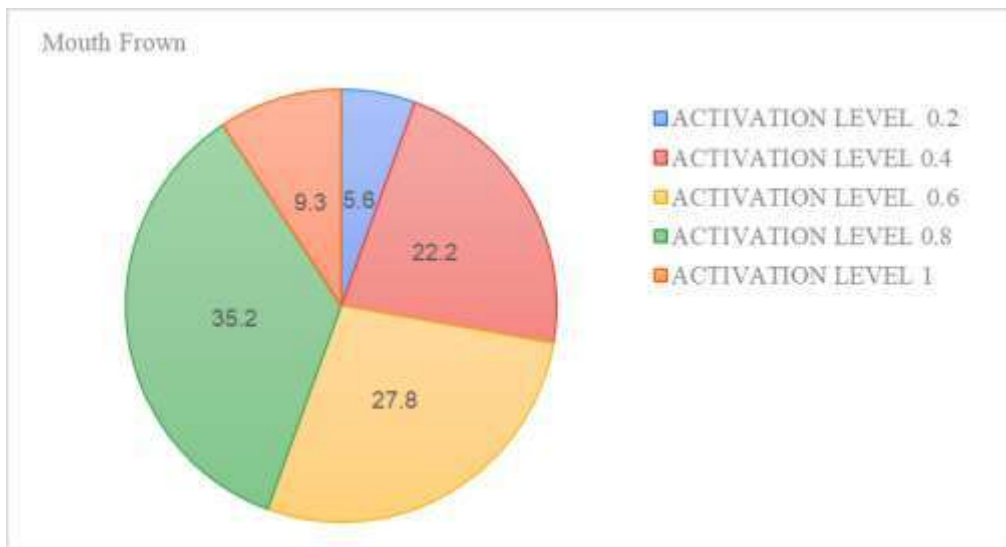
Figure 3.1.19 Percentage of AU activation level
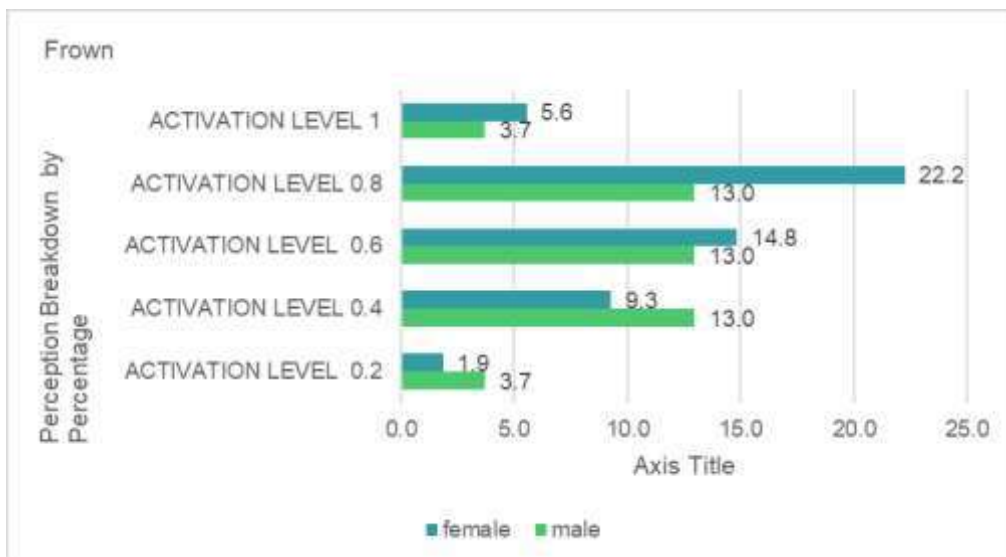
Figure 3.1.20 Percentage of AU activation level: Male - Female ratio

AU 26: Jaw Drop

Jaw Drop (খোলা মুখ) *
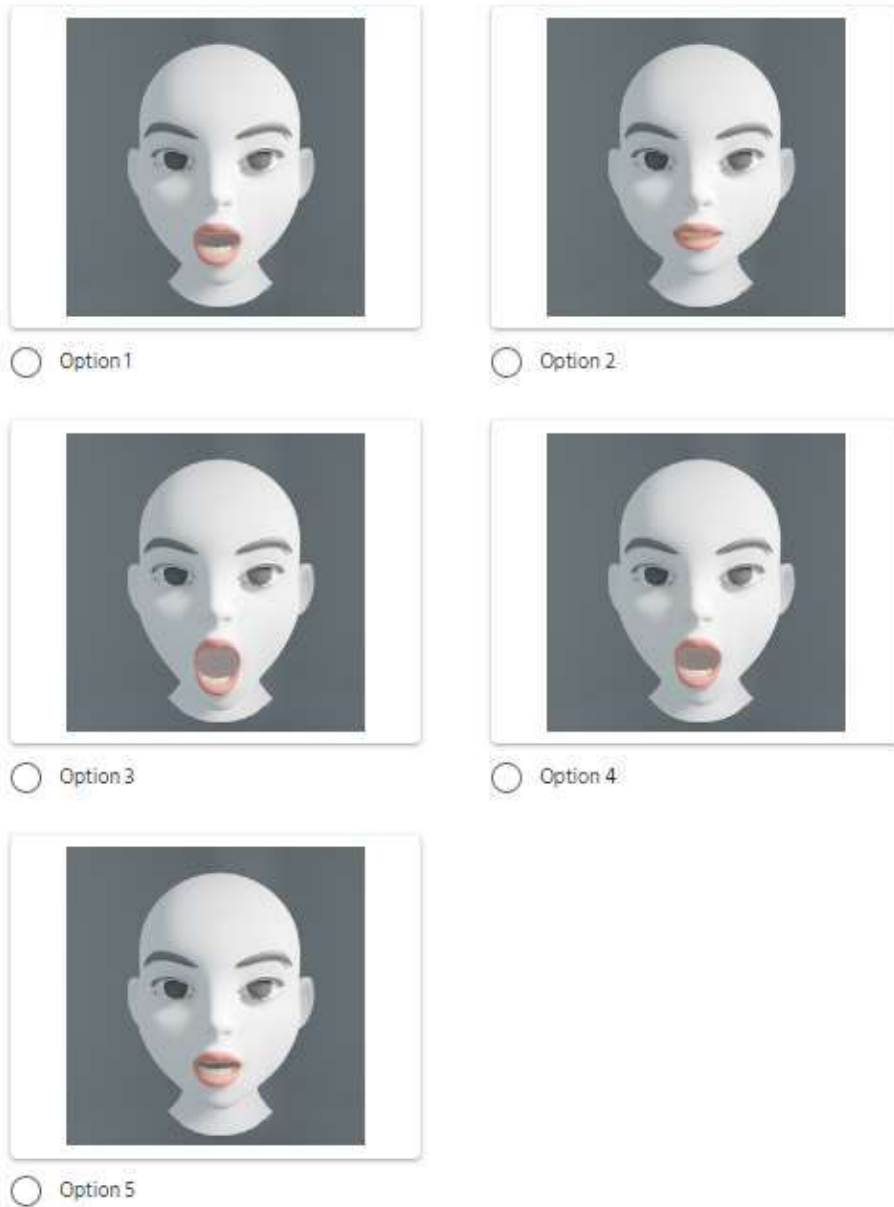
Figure 3.1.21 AU 26: Jaw Drop

Option 1-   0.6
Option 2-   0.2
Option 3-   1.0
Option 4-   0.8
Option 5-   0.4

Survey Result:
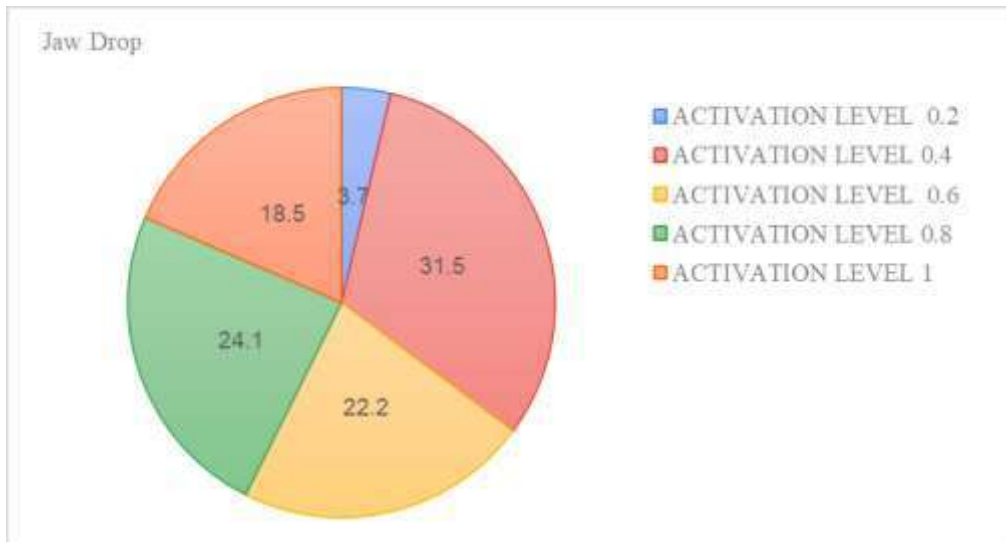
Figure 3.1.22 Percentage of AU activation level
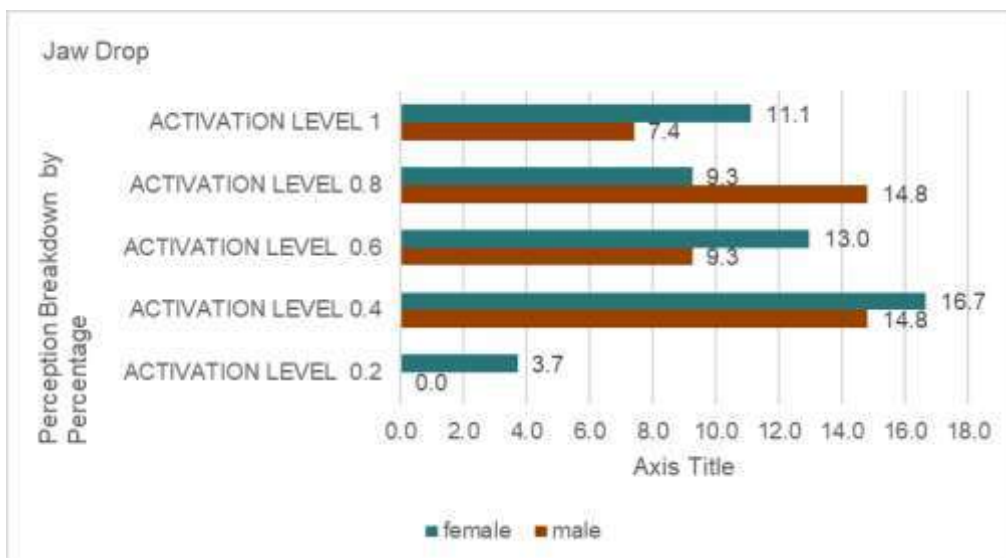
Figure 3.1.23 Percentage of AU activation level: Male - Female ratio

AU 38: Nostril Dilator

Nostril Dilator (নাক কুঁচকানো) *

Figure 3.1.24 AU 38: Nostril Dilator

Option 1-   0.2
Option 2-   0.8
Option 3-   1.0
Option 4-   0.6
Option 5-   0.4
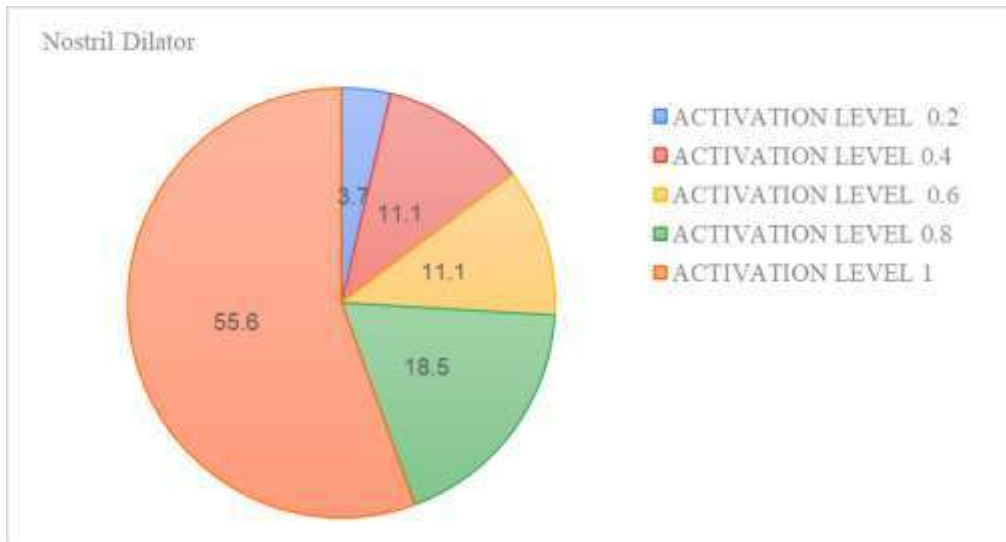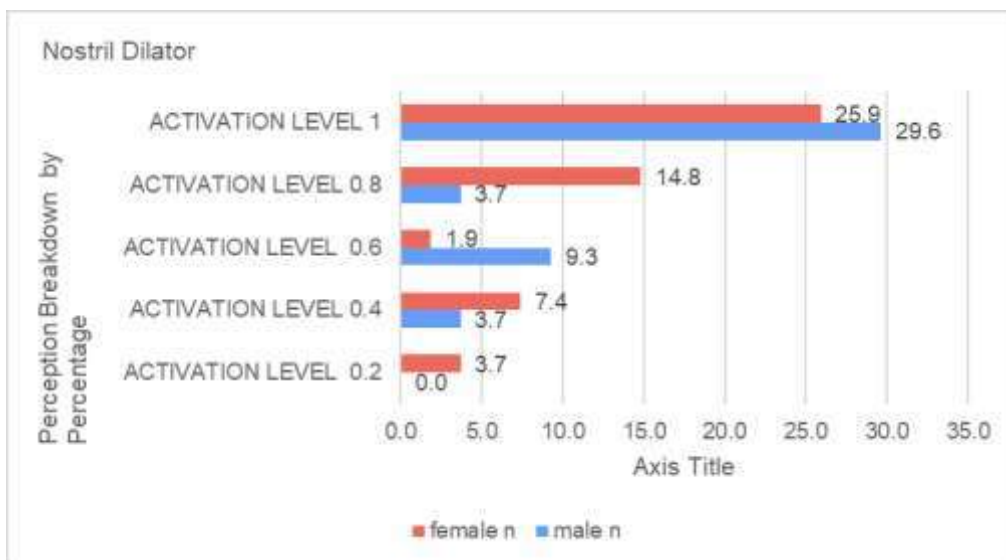
42

Survey Result:

Figure 3.1.25 Percentage of AU activation level

Figure 3.1.26 Percentage of AU activation level: Male - Female ratio

AU 18: Lip Pucker

Lip Pucker (ঠোঁট কুঁচকানো) *
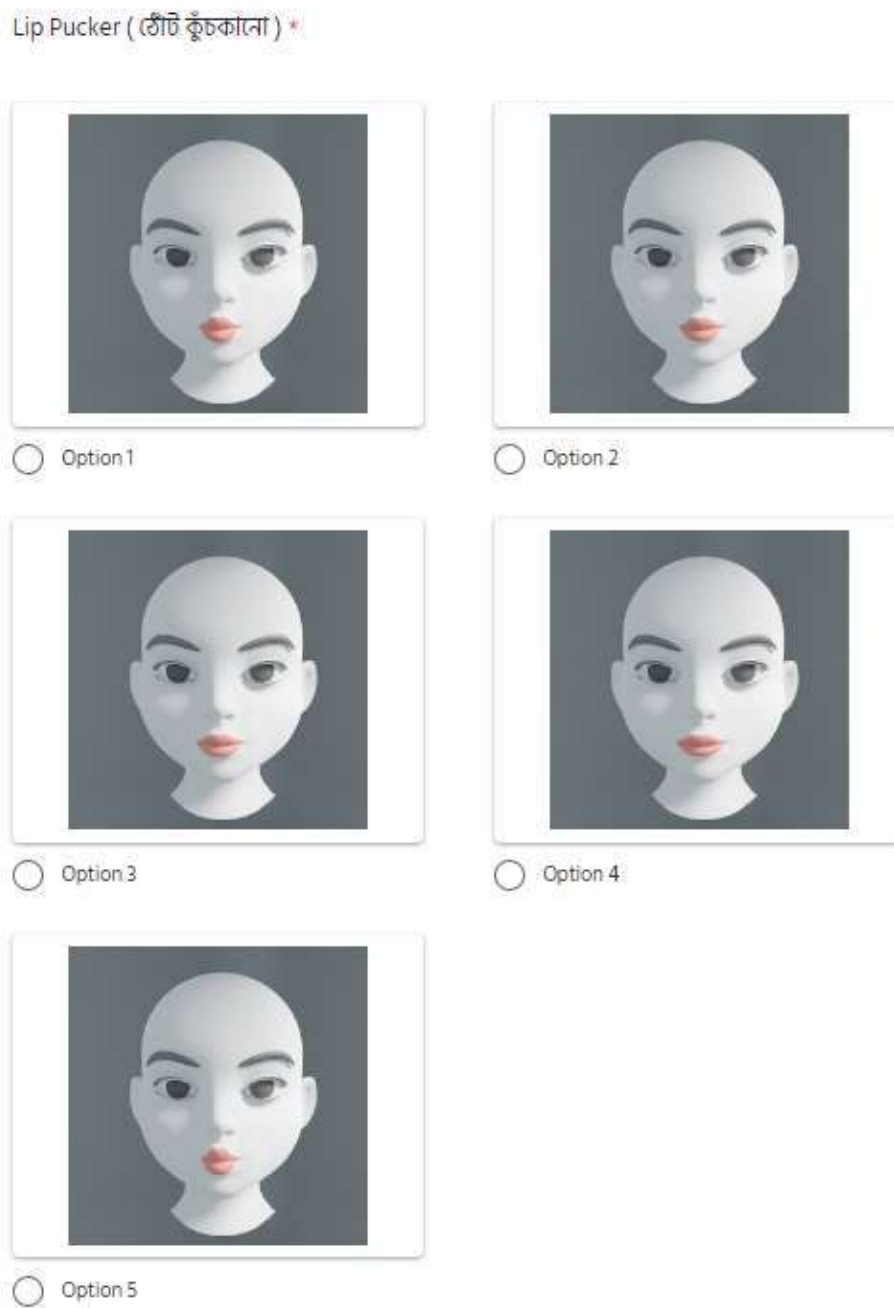
Figure 3.1.27 AU 18: Lip Pucker

Option 1-	0.8
Option 2-	0.6
Option 3-	0.4
Option 4-	0.2
Option 5-	1.0

44

Survey Result:
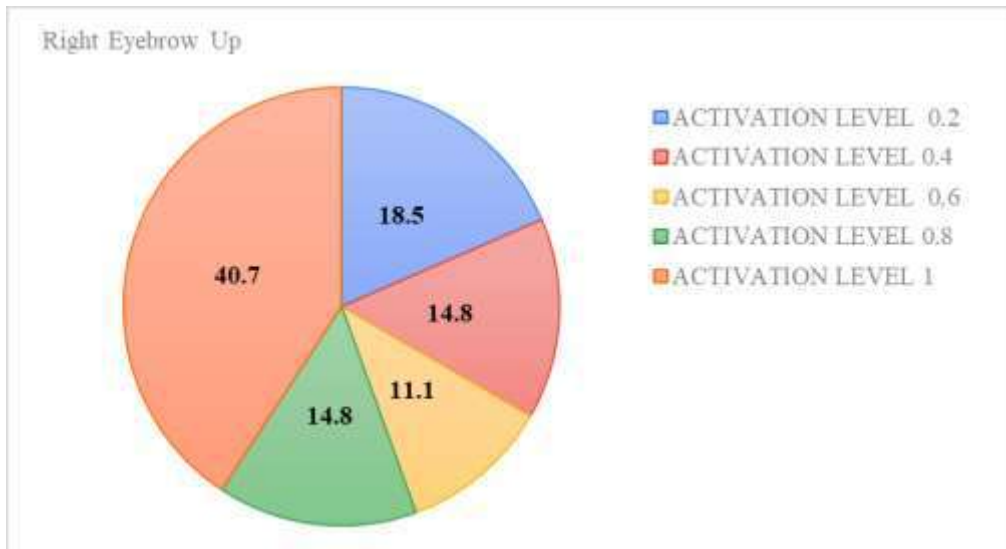

Figure 3.1.28 Percentage of AU activation level

Figure 3.1.29 Percentage of AU activation level: Male - Female ratio

AU 34: Cheeks Puffed

Cheeks Puffed (গাল ফোলানো) *

Figure 3.1.30 AU 34: Cheeks Puffed

Option 1-   1.0
Option 2-   0.2
Option 3-   0.6
Option 4-   0.4
Option 5-   0.8

Survey Result:
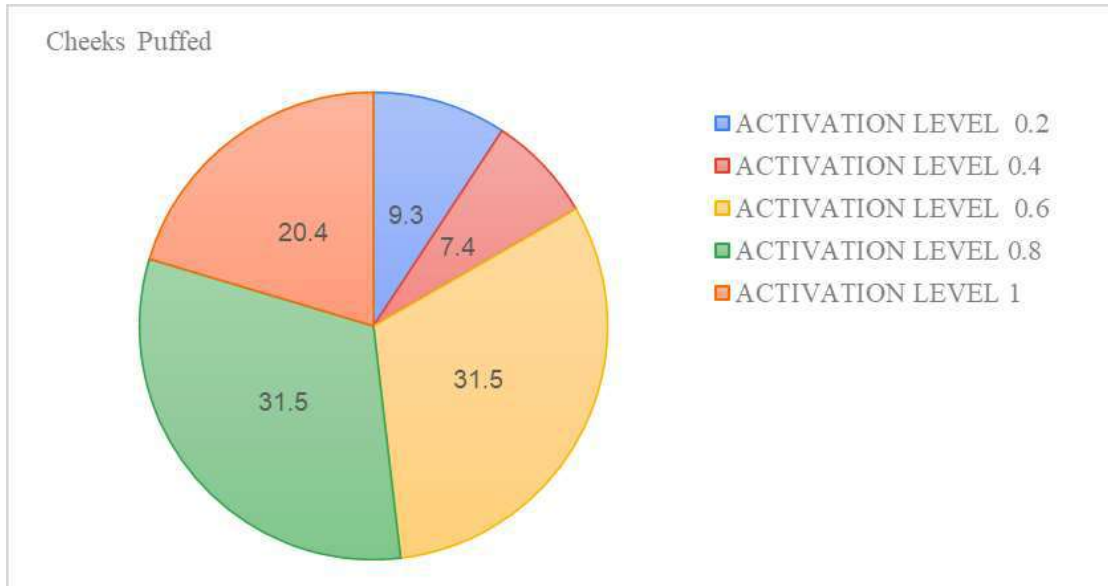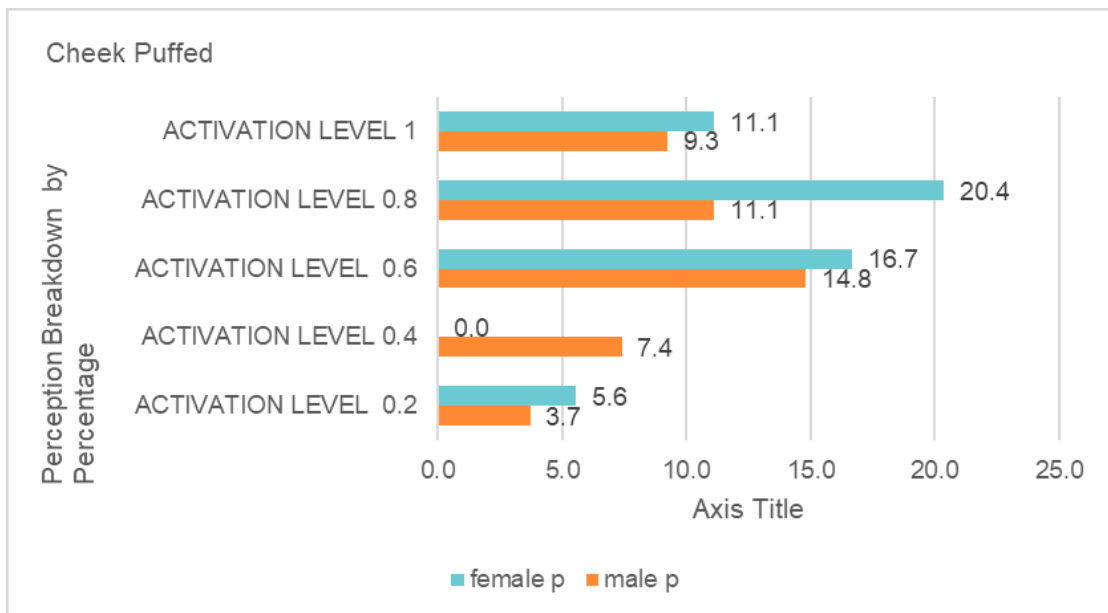
Figure 3.1.31 Percentage of AU activation level
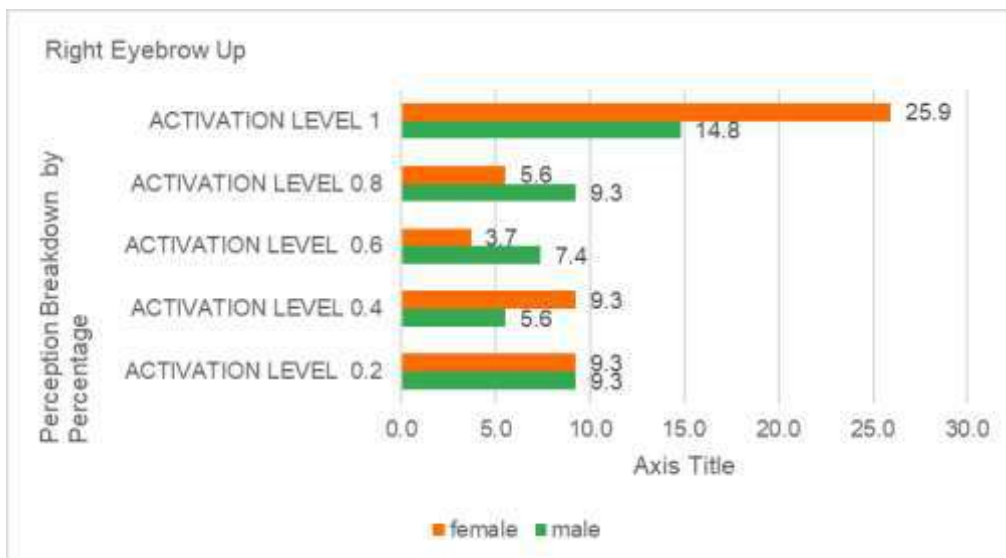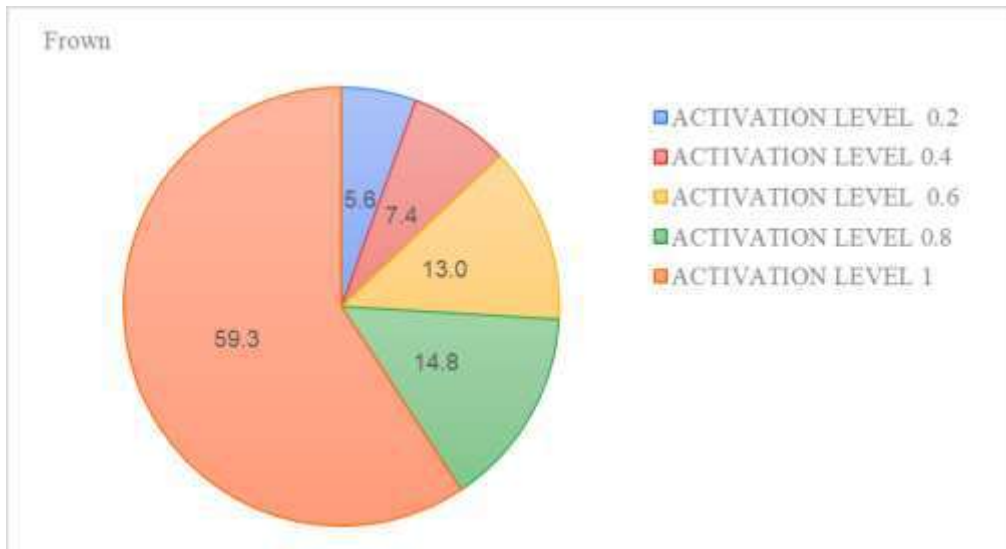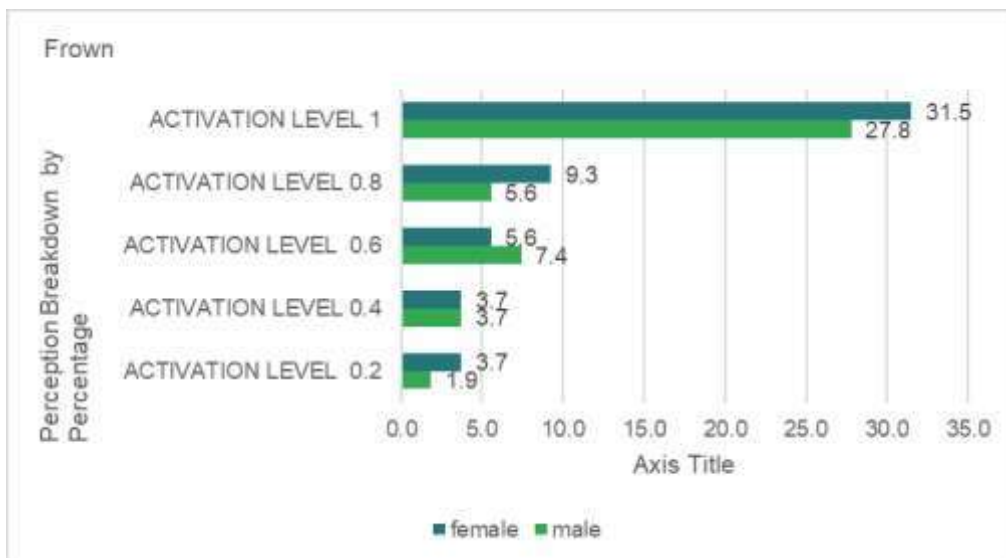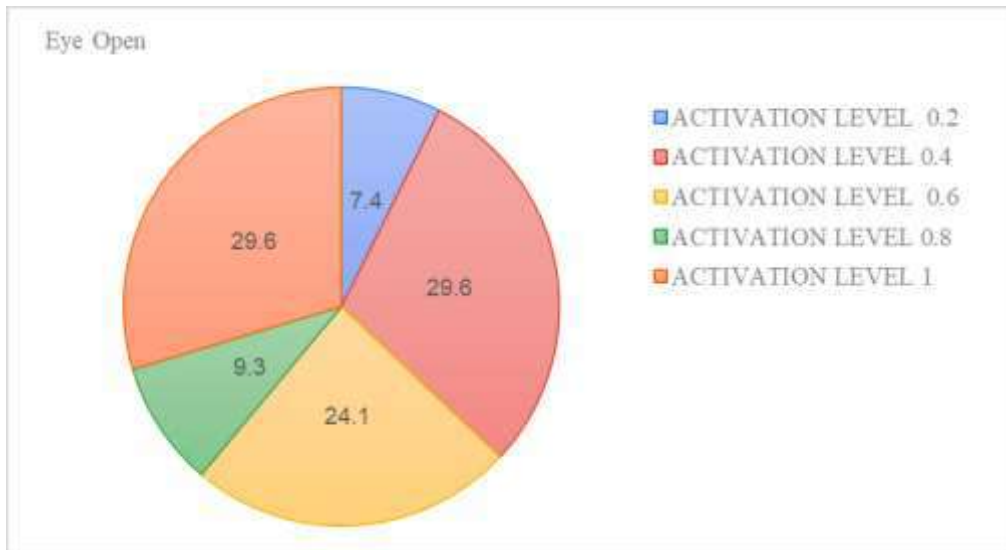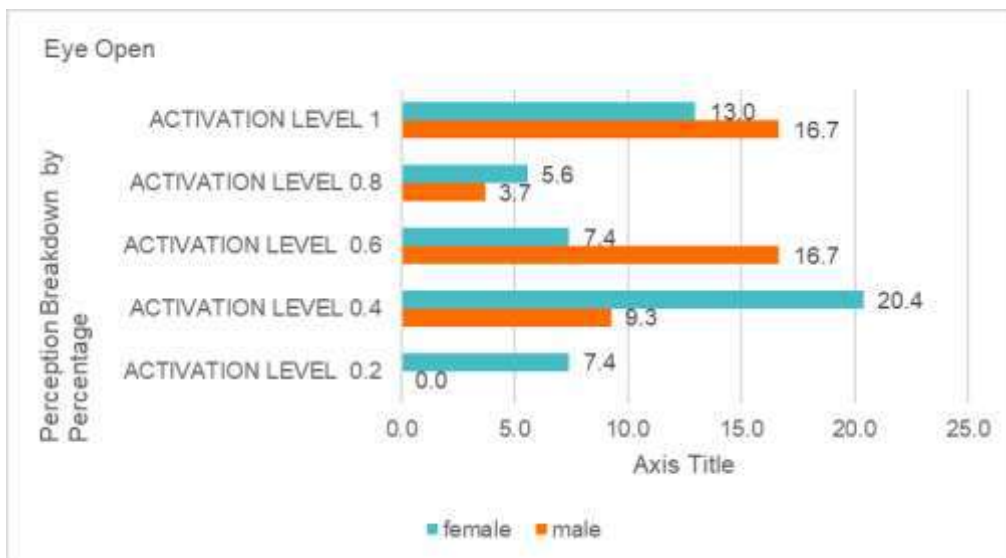

Figure 3.1.32 Percentage of AU activation level: Male - Female ratio

3.2 Charts, Calculations and ANOVA Interaction

From the Survey, we get a total of 54 Inputs from unique participants. We can analyze those data for better understanding the trend of perception.

Table 2: Table of total number of activation par action unit

		AU 2	AU 4	AU 5	AU 12	AU 15	AU 26	AU 38	AU 18	AU 34
Total number of activations	0.2	10	3	4	2	3	2	2	1	5
	0.4	8	4	16	3	12	17	6	6	4
	0.6	6	7	13	13	15	12	6	5	17
	0.8	8	8	5	14	19	13	10	12	17
	1.0	22	32	16	22	5	10	30	30	11
Sum		54	54	54	54	54	54	54	54	54

From Our survey, we randomly chose 11 participants from each group of Male (15-25), Male (26-35), Female (15-25) and Female (26-35) to be used in two-way ANOVA interaction. ANOVA Interactions are used to determine whether two or more factors have any effect on the result produced. We have to take 3 null hypotheses first, and if the value of F-distribution is greater than F-critical value, we reject the null hypothesis.

Anova Interaction between Gender and activation level of 9 Action Units:

Hypothesis 1: Gender has no effect

Hypothesis 2: Different Activation level has no effect

Hypothesis 3: Gender and activation together has no effect.

Table 3: Table of Two-way ANOVA between activation level and gender

Source of Variation	SS	df	MS	F	P-value	F crit
Sample	0.00	1.00	0.00	0.03	0.87	3.87
Columns	2.60	8.00	0.33	5.65	0.00	1.96
Interaction	0.42	8.00	0.05	0.90	0.51	1.96
Within	21.76	378.00	0.06			
Total	24.79	395.00				

As we can see, only the Activation Level (columns) has an effect on the result. Also, the p-value is less than the given significant level of .05. So, we can also reject Hypothesis 2 from here.

Anova Interaction between Gender and Age:

Hypothesis 1: Gender has no effect

Hypothesis 2: Age has no effect

Hypothesis 3: Gender and Age together has no effect.

Table 4: Table of Two-way ANOVA between gender and age

Source of Variation	SS	df	MS	F	P-value	F crit
Sample	0.00	1.00	0.00	0.01	0.91	4.08
Columns	0.01	1.00	0.01	0.74	0.40	4.08
Interaction	0.01	1.00	0.01	0.74	0.40	4.08
Within	0.55	40.00	0.01			
Total	0.57	43				

Here we can see that none of the F- values is greater than F-critical value. So, all of the null hypotheses are true. So, Gender, Age or their combination has no effect on the perception of BlendShapes.

Chapter 4
METHODS

We now have a clear direction for our work from the previous chapter. We must follow the guidelines provided and experiment as needed to reach our goals. These are the four steps we have to take in order to achieve that:

1. The face must be sculpted and retopologized using a reference image. The next step is to construct and rename all of the BlendShapes models that we want to see in the finished model, in this case, all 52 of them.

2. Importing the BlendShapes into Unity Engine and configuring it to make the most use of the data from those BlendShapes in order to prepare it for live face tracking.

3. Creating a basic third-person character, inserting unique animation, and integrating the face and body to make it come to life.

4. Setting up the scene in Unity and making the necessary adjustments to the lighting, volume, and other parameters.

4.1 Software Used in this Project

Table 5: Table of Software used

Function	Software used		Format
Mesh Convertion	ZBrush		.stl to .obj
Retopology	Autodesk Maya		.obj
BlendShapes	Blender		.obj to .fbx
FaceTrack	Apple ARKit		C#
Motion Capture	Mixamo		.fbx for Unity
Game Engine	Unity		.fbx , C#
Data Analysis	MS Excel		.xlsx

4.2 Converting Base Mesh

The Base Mesh that is used in this project is a base model provided by Apple, with a creative commons license. The model is in stl format, that's why I imported it to ZBrush. ZBrush is a sculpting software, but it can also be used to convert and re-mesh existing meshes from high-poly to low-poly or from one type of mesh data to another.
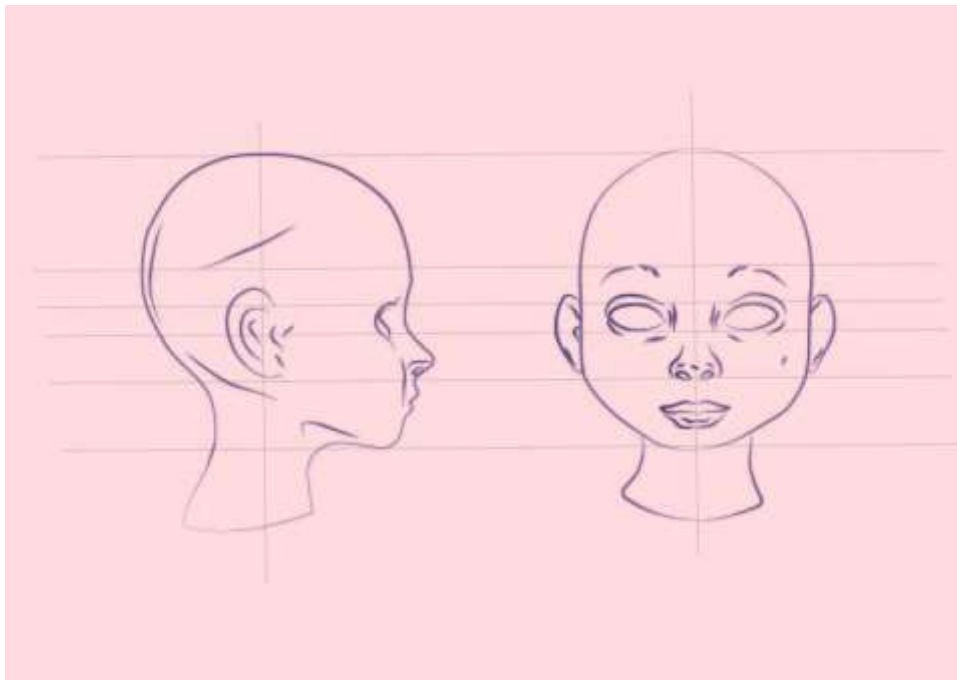
Figure 4.2.1 Head Reference

Apple also provides above reference image, because most of the time, when converting any model from one format to another, the model loses some of its general form. All we need to do is use some basic brushes to fine-tune some of the original details back to the mesh. We can do that manually, or there are some built in tools inside ZBrush for projecting such details back to the relatively low-poly model.

Figure 4.2.2 ZBrush brushes

1. Refine the sculpt: Continue to refine the sculpt using a variety of sculpting tools and techniques. Pay attention to the overall shape of the face, as well as the smaller details.
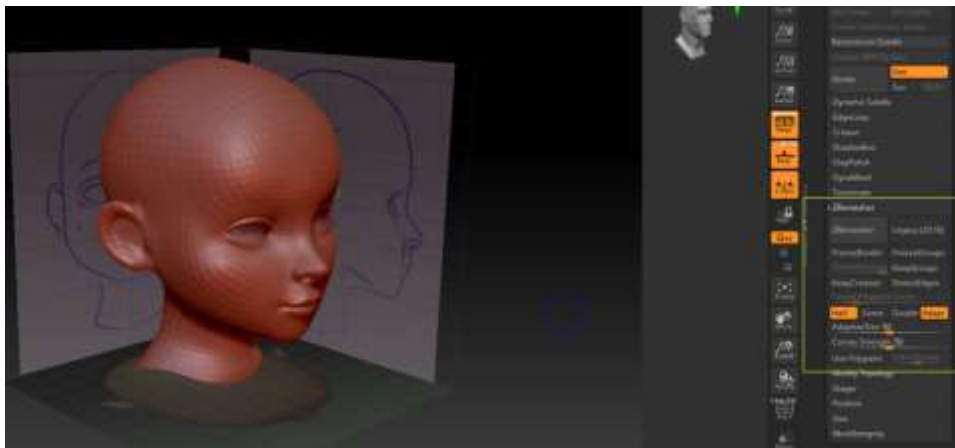
Figure 4.2.3 ZRemesher for Higher polygon

2. Export the model: When you are finished sculpting, export the model as an .obj file or other suitable format for use in other software.

Alternate Way to achieve similar result:

Although not used in this project, I feel obligated to include this section here. Photo scanning or photogrammetry. Technologies such as infrared camera or LIDAR is used to accurately measure such data, than those are cleaned in any 3d software such as Maya or Blender. Reason I did not chose to go that route is, the setup that is needed to avail such detailed scan requires multiple cameras which are interconnected to capture all at once. I did not have such luxury. If I did, I would most certainly use that to create a face of my own. Applications like Metahuman, Make Human or Character Creators are all GPU-intensive or paid service which makes them ineligible to be used in this project.

There are also some services available where softwares can create 3d Models just from bunch of images. But that technology is also in its infancy and it doesn't have the necessary control I needed for tis project. But all of them has the potential to replace digital sculpting in future.

55
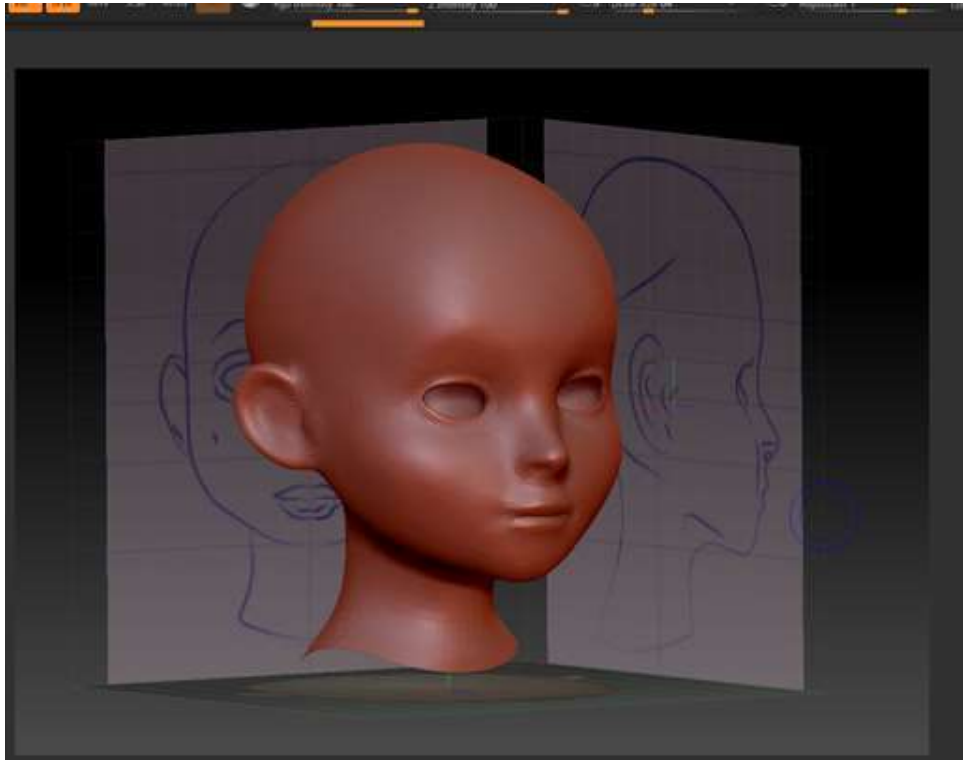
Figure 4.2.4 Finalized Version of the sample model

4.3 Retopology

My chosen tool for retopologizing the model was Autodesk Maya. The Quad Draw mode in the Modelling Toolkit in Maya is a powerful retopology tool. Edgeflow maintenance is made simpler by using this tool. To retopology in Maya using the Quad Draw modeling toolkit, I will follow these steps:

1. First, I will select the base mesh that I want to retopologize in the Modeling tab. Then I will make the model a Live Object, so it can't be selected.

2. Next, I will enter quad draw mode by clicking the "Enter Quad Draw" button in the Quad Draw tab.

Figure 4.3.1 Maya Retopology

3. Using the Quad Draw tools, such as the Quad Draw brush and the Loop and Ring tools, I will create a new topology for the base mesh. This will involve drawing a series of quads over the surface of the base mesh, following the contours and details of the model.

4. As I work, I will adjust the topology as needed, adding or deleting quads as needed to refine the mesh.

Figure 4.3.2 Live Object & Quad Draw

5. When I am happy with the topology, I will use the "Project All" command in the Quad Draw tab to project the topology onto the base mesh, creating a new mesh with the desired topology.

Figure 4.3.3 More Edge Loops!

6. To clean up the mesh, I will use tools such as the Merge and Weld tools to remove any unnecessary vertices or edges. Then I sub-divided the mesh, ready to be exported as FBX format.

Since Edgeflow has an impact on the model's overall quality and realism, it is crucial to take it into account while modeling faces. Edgeflow is the arrangement and connection of a 3D model's edges, and it affects how the model deforms and moves during animation.

When a model is animated, a proper Edgeflow makes sure that it deforms smoothly and organically without producing unfavorable artifacts like pinching or stretching. This is crucial for facial animation since the face is one of the body's most expressive and dynamic organs, and viewers may pick up on even minor deviations.

Figure 4.3.4 Facial EdgeFlow in Maya

4.4 Making BlendShapes

Figure 4.4.1 ShapeKey (BlendShapes) Editor in Blender

BlendShapes, a technology that has proven indispensable in the realm of 3D animation, enable artists to produce more emotive and lifelike figures. The capacity of BlendShapes to produce lifelike face expressions is one of its main benefits. The adaptability of BlendShapes is another benefit. They are easily adaptable and may be changed to produce a wide variety of forms and animations since they are dependent on minor adjustments to the rest posture mesh. This enables animators to explore and test out various concepts, leading to more original and dynamic animations. I chose Blender as my preferred software, because of the robustness it offers in terms of creating ShapeKey (BlendShapes are called ShapeKey in Blender). The sample BlendShapes were provided by Apple ARKit, which I tweaked and shaped as needed. Here is A step by step guide for making BlendShapes in Blender:

1. First, I will start with a base mesh of the face that includes all of the main features of the face, such as the eyes, nose, mouth, and ears.
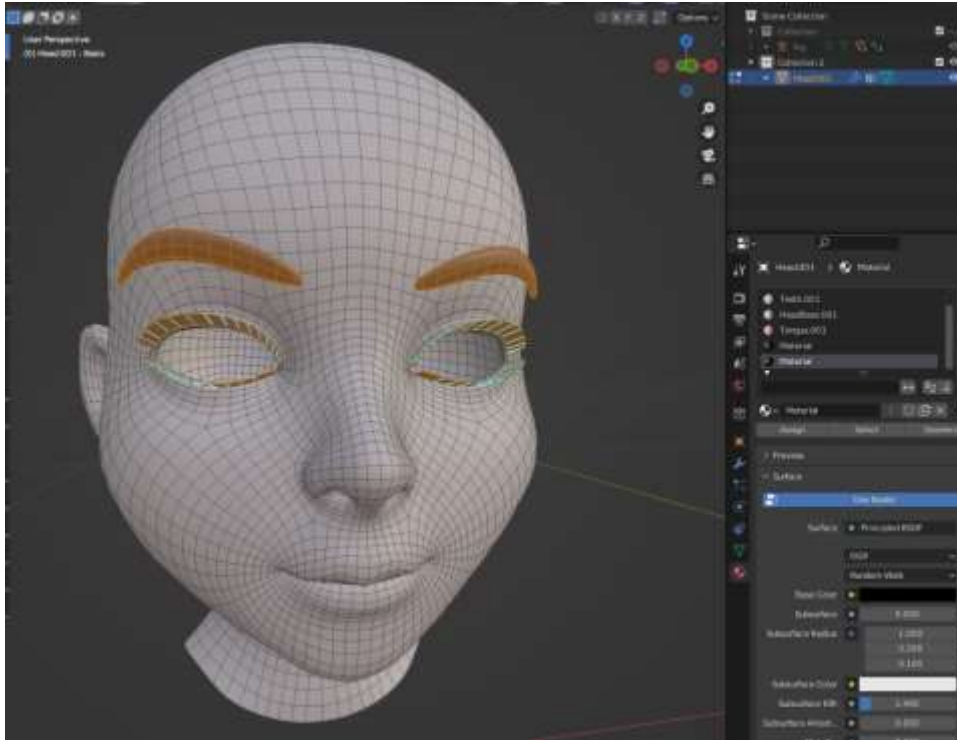
Figure 4.4.2 Landmark Placement (Object those should move with face i.e.: brow)

2. For each BlendShapes I want to create, I will create a new object in Blender. This object will be used to define the shape of the BlendShapes.

3. Using modeling tools such as the Extrude, Scale, and Loop Cut tools, I will modify the shape of the BlendShapes object to define the shape of the BlendShapes.

4. In the Object Data properties panel, I will click the "Add Shape Key" button to add a shape key to the base mesh.

5. In the Shape Keys properties panel, I will click the "Add Driver" button and select the BlendShapes object as the driver. This will link the shape of the BlendShapes object to the shape key.

Figure 4.4.3 All Required Blendshapes

6. I will repeat this process for each BlendShapes I want to create, creating a new object and shape key for each BlendShapes.

Figure 4.4.4 Base Mesh

Figure 4.4.5 RightBrow

Figure 4.4.6 Left Brow

Figure 4.4.7 Eye Squint

Figure 4.4.8 Eye Look Right

64

Figure 4.4.9 BlendShapes in Making

7. Once I have created all of the BlendShapes, I will test them by adjusting the value of each shape key in the Shape Keys properties panel. This will allow me to see how the BlendShapes deform the base mesh.
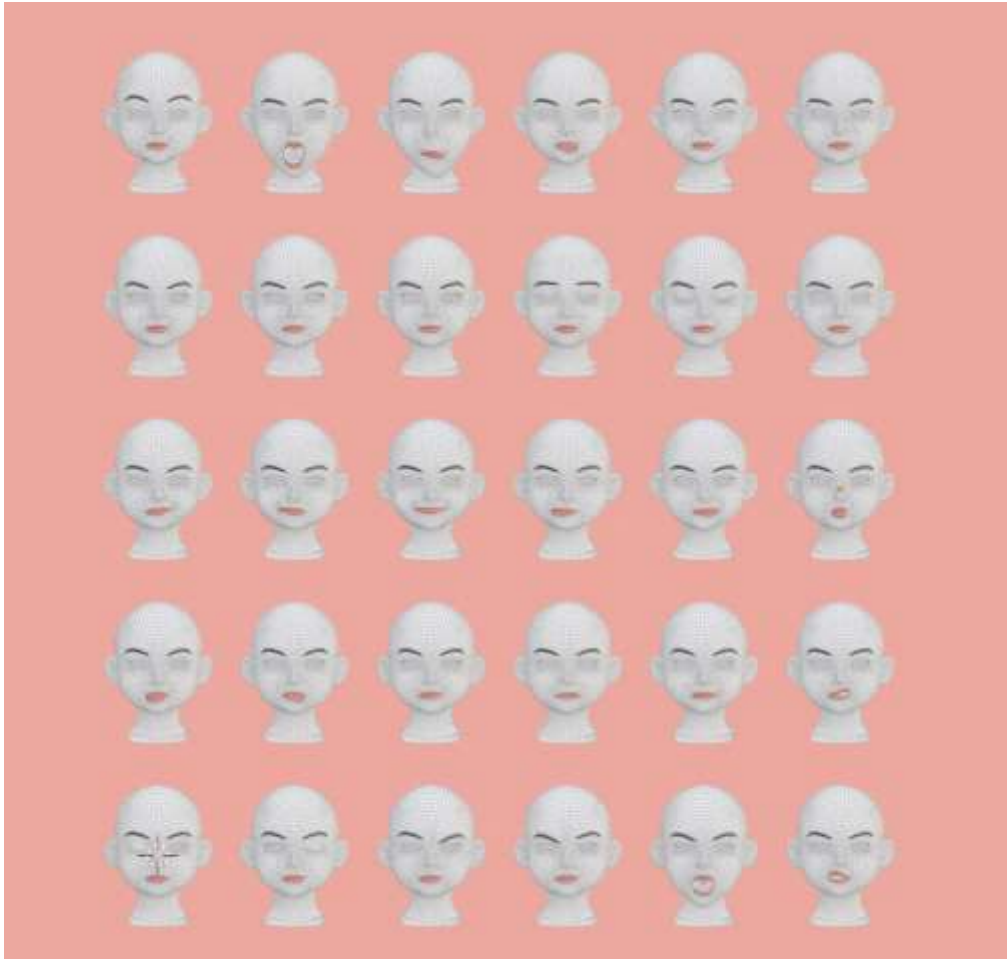
Figure 4.4.10 Side by Side

4.5 Virtual Avatar in Unity

Unity is a 2D and 3D game engine that was first released in 2005. It was created by Unity Technologies to provide more creators access to game production tools, which was a unique idea at the time. The engine has altered and grown substantially during its lengthy life, keeping up with the most recent methods and innovations. I picked Unity over Unreal Engine for live tracking for two reasons: first, it is less GPU intensive, and Unity is easier to use.

4.5.1 Mixamo to Unity:

After choosing a Body mesh to be attached with the face, I imported the mesh to the Mixamo platform to be rigged. Then I followed below steps-

1. Go to the Mixamo website and sign in.
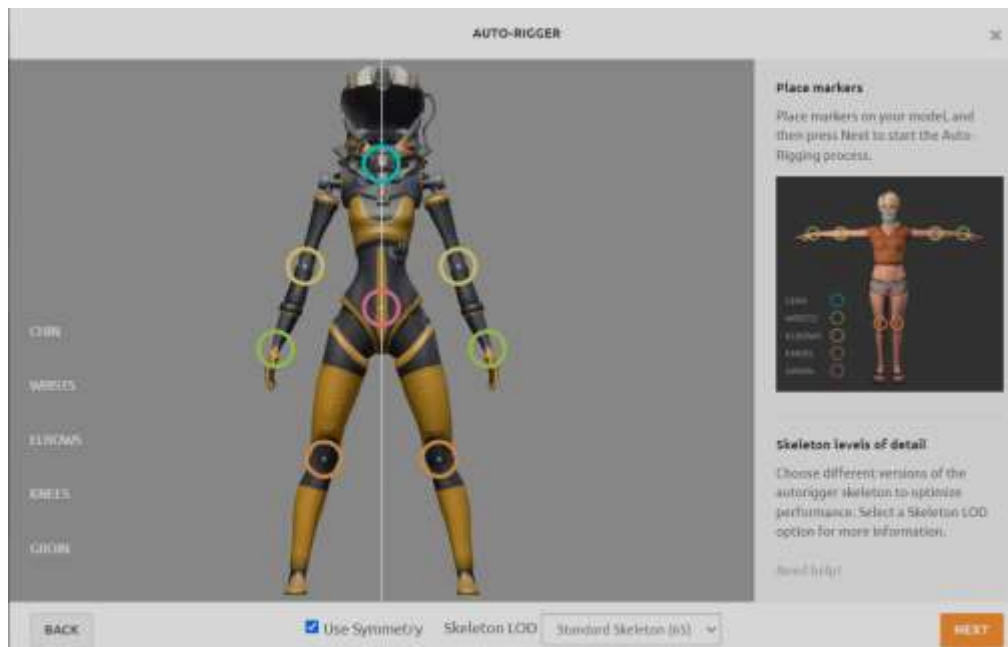
Figure 4.5.1.1 Getting Character rigged in Mixamo

2. Browse for the animation you want to use and click on it to select it.

3. Click on the "Download" button and choose the "FBX for Unity" option from the dropdown menu.
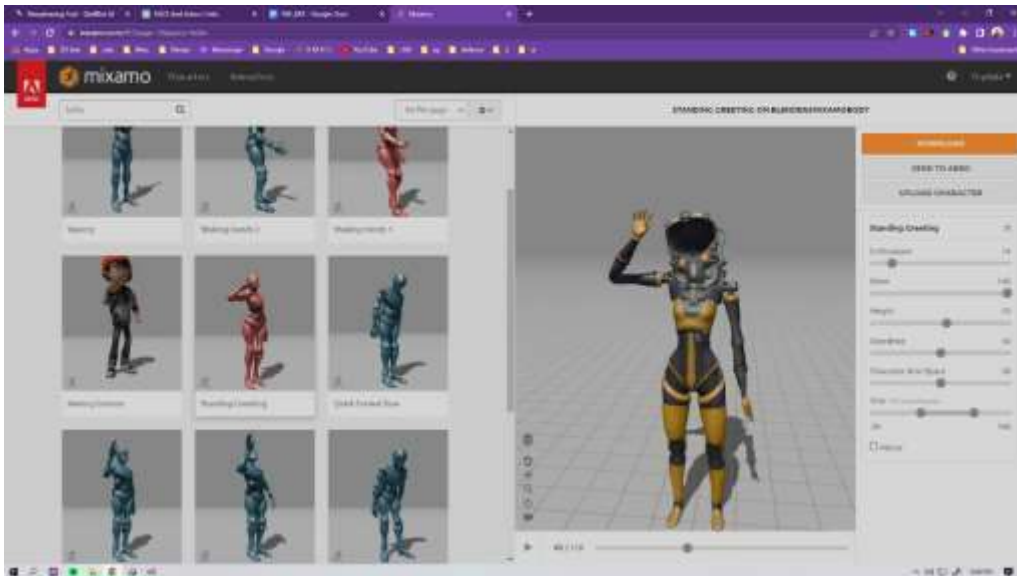
Figure 4.5.1.2 Downloading preferred animation, Without Skin, FBX for Unity

4. Save the downloaded FBX file to a location on your computer.

5. In Unity, go to "Assets > Import Package > Custom Package" and select the downloaded FBX file.

6. In the Import Unity Package window, click on the "Import" button to import the animation into your Unity project.

Figure 4.5.1.3 The Body is Rigged in Mixamo

7. Drag the animation file from the "Project" window to the object in your scene to apply the animation.

Figure 4.5.1.4 The helmet is a child of the body

4.5.2 Unity Animation & BlendTree

Figure 4.5.2.1 Animation Motions from Mixamo
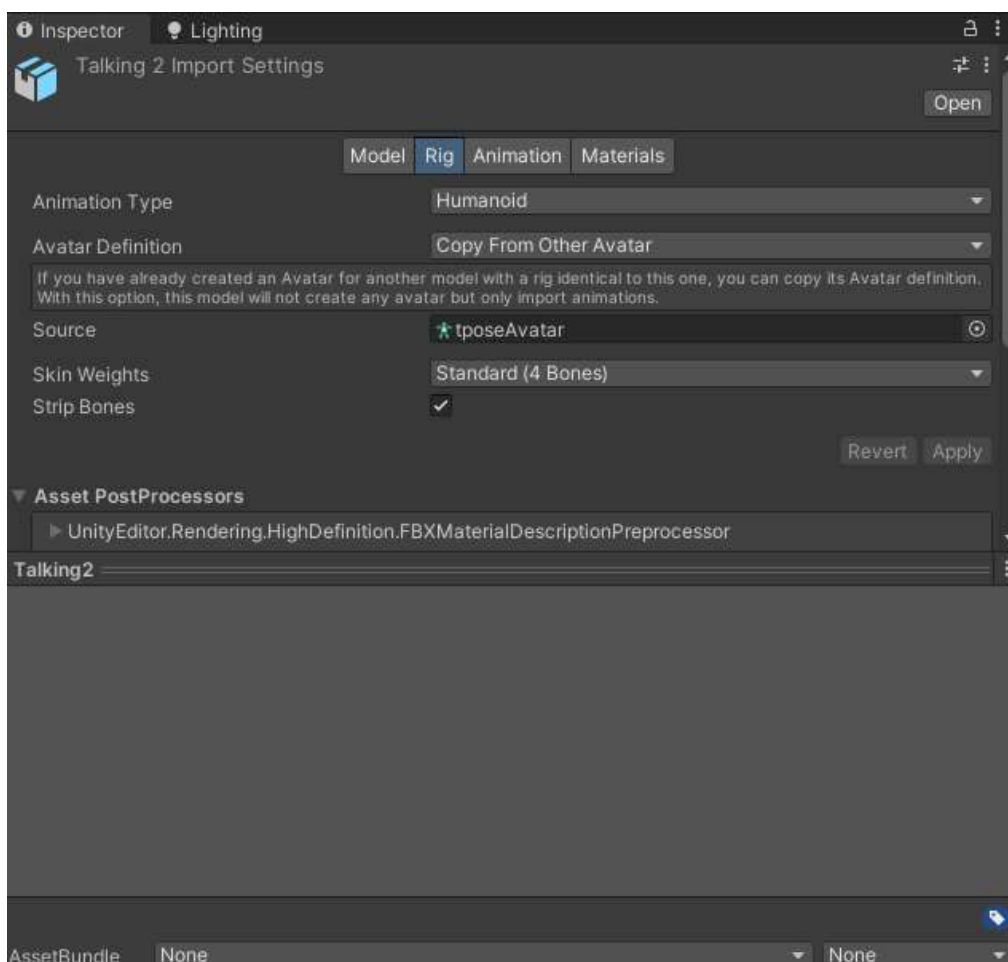
Figure 4.5.2.2 All animations have to Rigged Humanoid, with Avatar source from the Body

To set up a blend tree animation in Unity for a character, we can follow these steps:

1. In the "Project" window, create a new "Animator Controller" and name it.
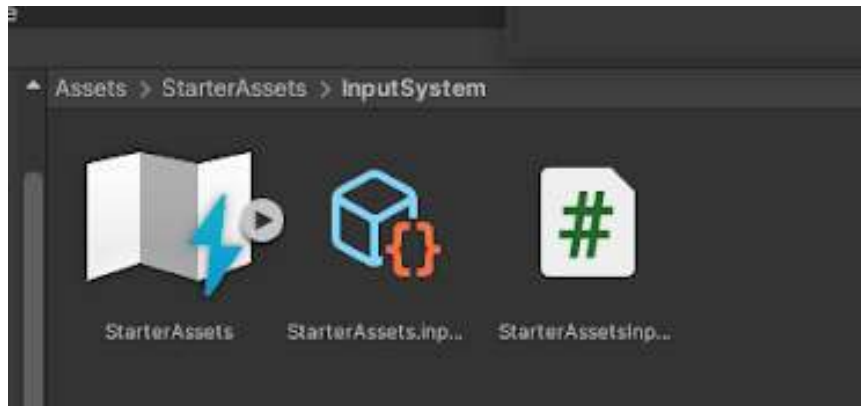
Figure 4.5.2.3 Unity new input system

2. Double-click on the new Animator Controller to open it in the Animator window.
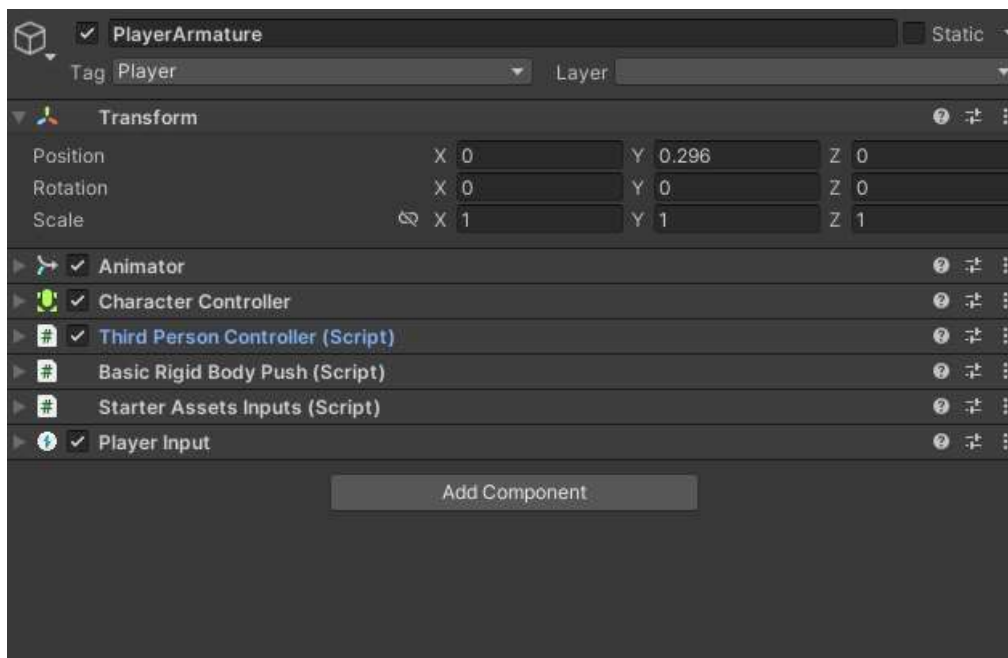
Figure 4.5.2.4 Components of the character

3. In the Animator window, right-click on the blank area and select "Create State > Empty" to create a new state.
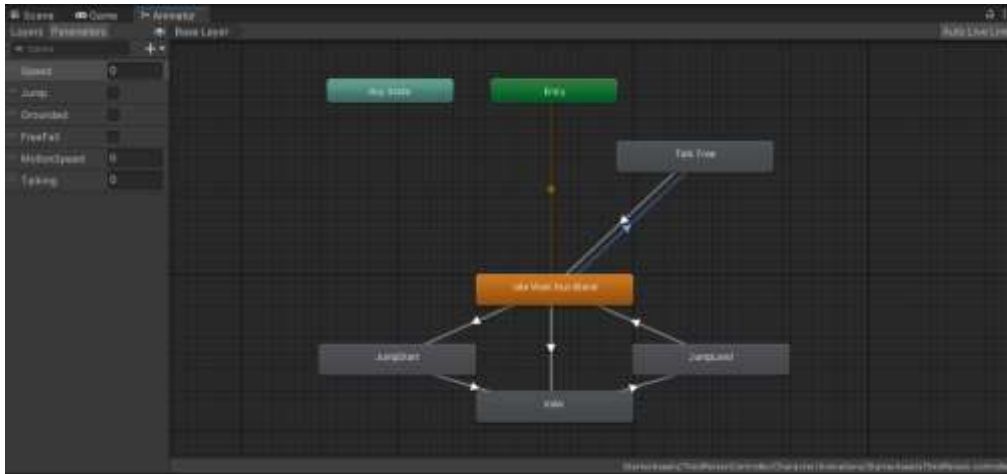
Figure 4.5.2.5 Animator window with BlendTree

4. Right-click on the new state and select "Make Transition" to create a transition from the default state to the new state.
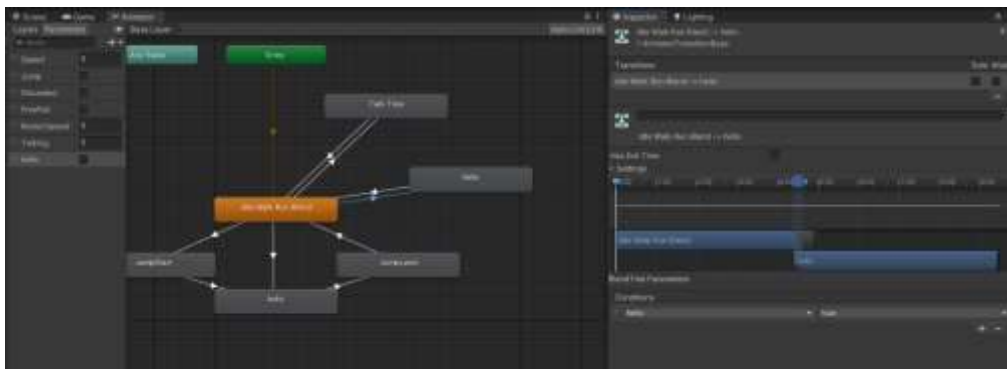
Figure 4.5.2.6 Animation state transitions needs to have parameters to functions

5. In the "Inspector" window, click on the "Motion" field of the new state and select the animation clip that you want to use in the blend tree.

6. Right-click on the new state again and select "Create State > Blend Tree" to create a blend tree state.

7. In the "Inspector" window, set the "Blend Type" to "1D" and click on the "+" button to add animation clips to the blend tree.

8. Set the parameters that will control the blend tree, such as speed or direction.
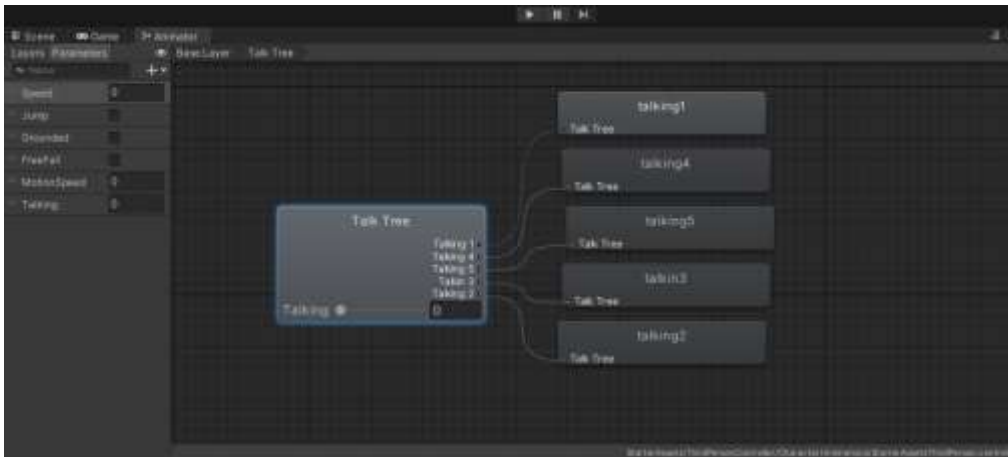
Figure 4.5.2.7 Talk Tree blend tree

9. Connect the blend tree state to the default state with a transition and set the transition conditions based on the blend tree parameters.

10. Drag the Animator Controller onto the object in your scene to apply the blend tree animation.

4.5.3 Setting ARKit in Unity

To set up the BlendShape Data Face in Unity, we have to these step

1. Import the face From Blender to Unity.

Figure 4.5.3.1 Blendshape face from Blender

2. In the hierarchy, we have to make the Face a child of the Head-bone, so that it follows and rotates with the body properly.

74
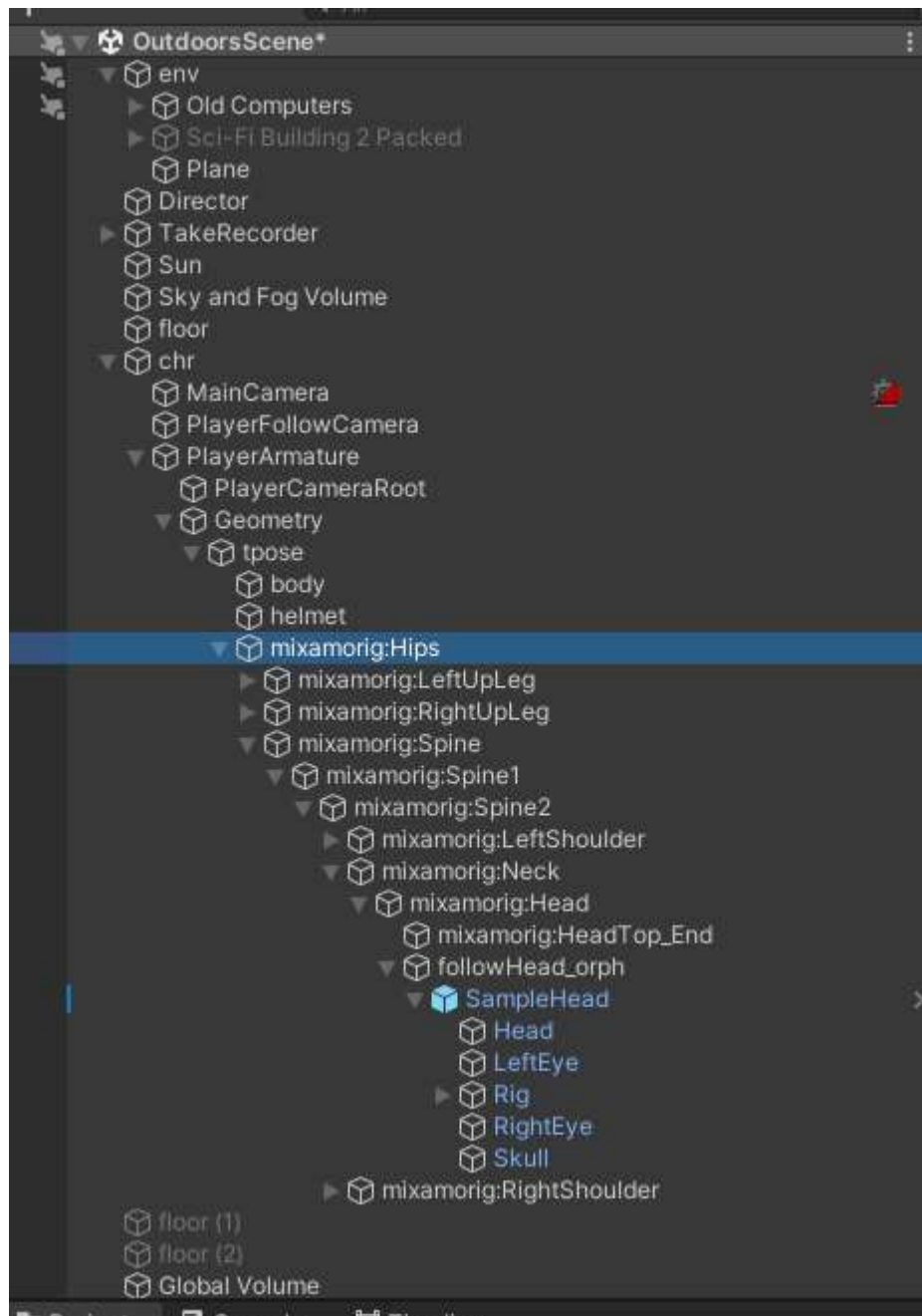
Figure 4.5.3.2 Scene Hierarchy

3. Download ARKit Live face track from Unity registry, and download Unity face track app on my apple device.
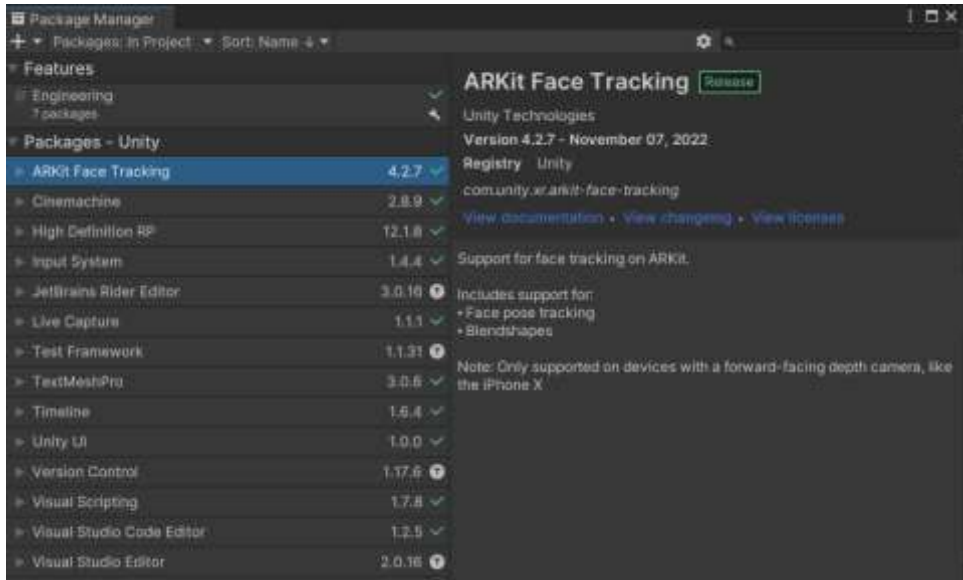
Figure 4.5.3.3 ARKit Package in Unity Registry

Figure 4.5.3.4 Unity Face Capture app in Apple app store

4. To set up properly, we have to take an Animator component, an ARKit Face Actor component and attach them to the face that have the BlendShapes.
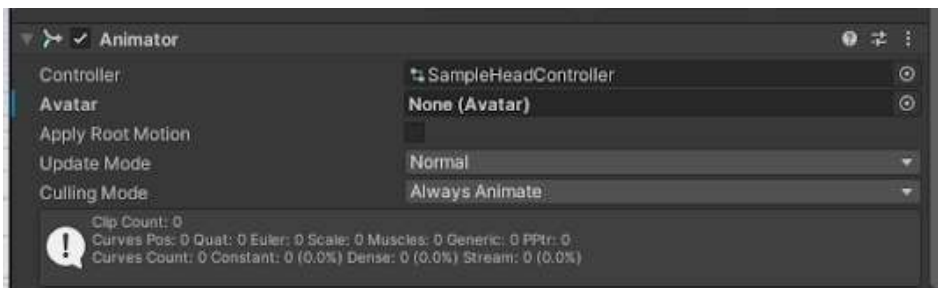
Figure 4.5.3.5 Animator Component for face

Figure 4.5.3.6 ARKit Face Actor Component for face, that enables BlendShapes

5. We have to take a Sample Face Mapper and attach it to the Face. This will communicate between the Unity Engine and the Live face tracking app.
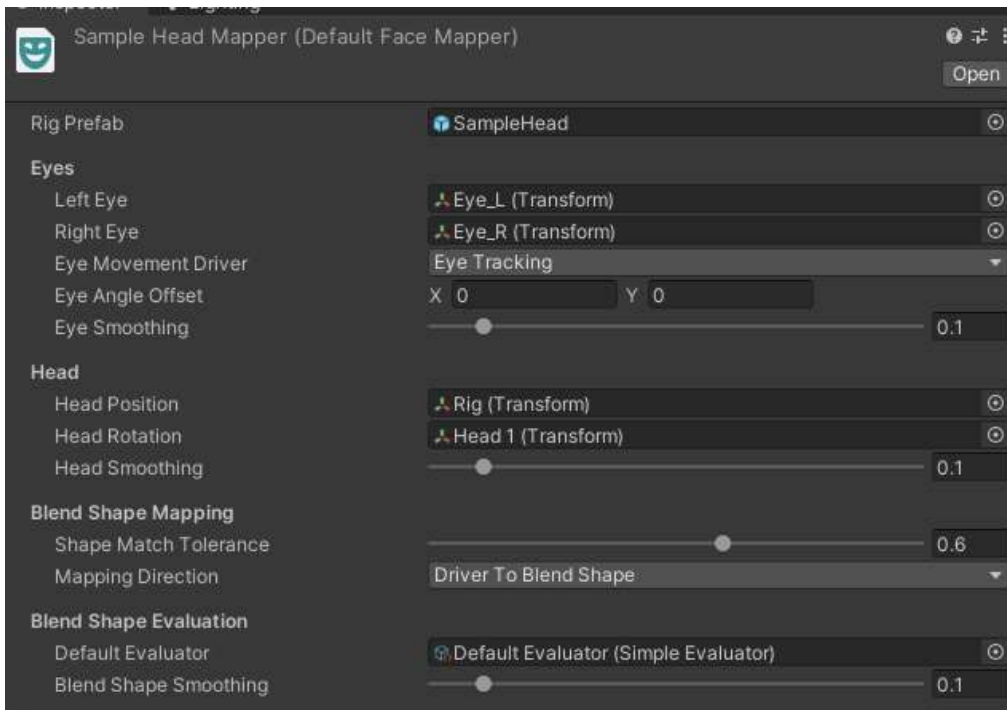
Figure 4.5.3.7 Head Mapper for face tracking
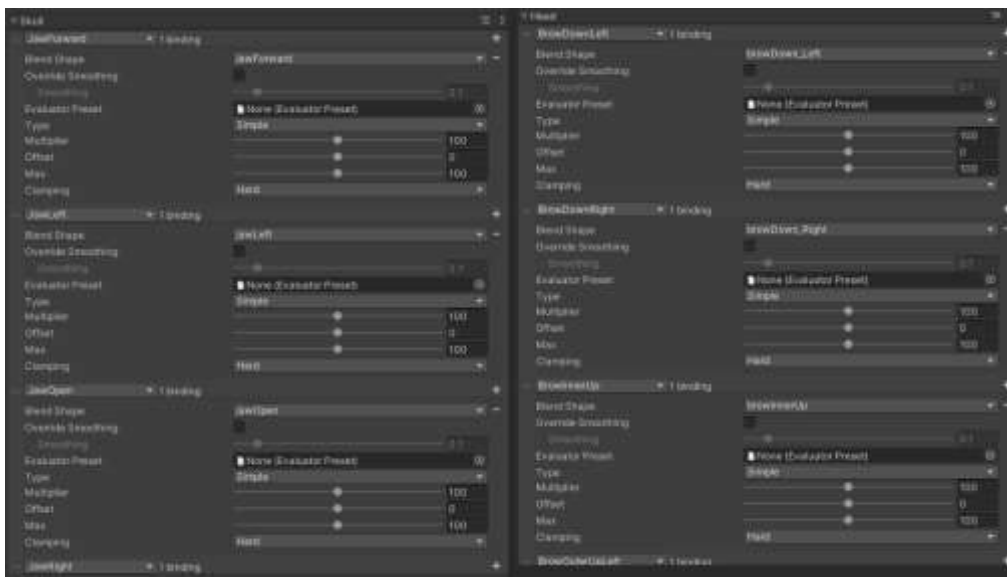
Figure 4.5.3.8 Skull & Head BlendShapes drivers

6. In the app, we have to position our face, calibrate the face for tracking and make necessary changes.

Figure 4.5.3.9 App Calibration

7. In Unity, we set up the project in specific way:
   a) Take Recorder in the hierarchy
   b) TimeLine in the Console Panel
   c) Connection in the Inspector panel- Creating a server for the app to connect
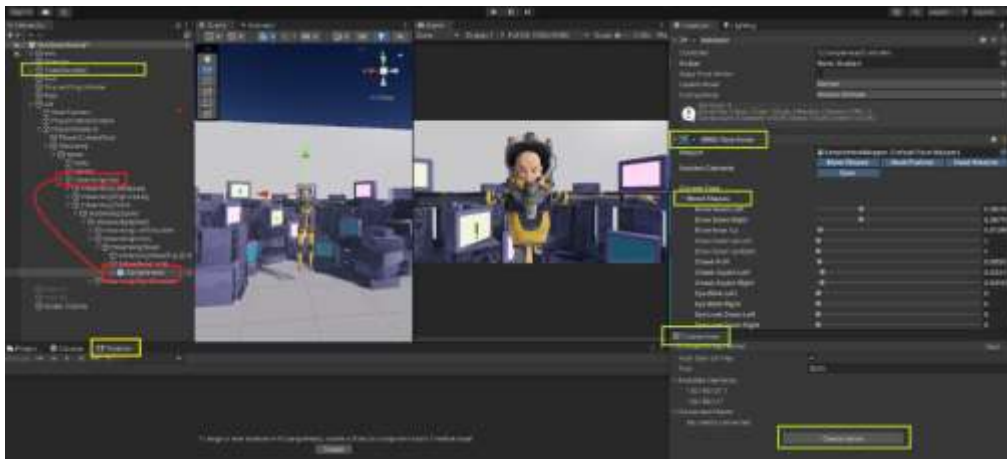
Figure 4.5.3.10 Exact way the Unity editor has to be set up for Face tracking

8. Start recording in the Apple device, and the face in Unity should start tracking

Chapter 5
DISCUSSION

From the previous chapter, we can come to some certain conclusions about our perceptions of facial BlendShapes. In the research paper *Investigating perceptually based models to predict importance of facial blendshapes* [1] the researcher came to three important conclusions:

a) Character Sex & Race: There was no main effect of the character Sex. However, we found a main effect of character Race

b) Activation Level: A main effect of Activation Level showed a significant increase in perceived differences as the activation increased, as expected.

c) Action Units: Mouth Open (Jaw Drop), Eyes Open, and Smile Lips Closed appeared to have a higher perceptual effect since the perceived differences were significantly higher when compared to all other AUs. Further interactions showed that Mouth Open was significantly more different than most other shapes.

Below is a radar-chart of the average value of each of the 9 Action Units. We can clearly see that Bangladeshi participants also do follow similar perceptions. But the effect is more prominent in mouth frown, than Smile.

Figure 5.1 Radar Chart of AU activation

We can further breakdown this into Male and Female perceptions by age groups.

Figure 5.2 Male and Female 15-25

Figure 5.3 Male and Female 26-35

We can also compare how different age groups of the same Gender perceive emotion.

Figure 5.4 Female AU activation by age-group

Figure 5.5 Male AU activation by age-group

Perception By activation of AU:

In the below chart, we can see the range of answers by activation level.

Figure 5.6 Activation level variation

Here is the same chart shown as male-female percentage:

Figure 5.7 Activation level variation: Male-Female Percentage

So, with all these analyzed Data, ANOVA interaction and charts, we can confidently come to these conclusions:

a) Participants gender has no real effect on the selection of AU activation level
b) Selection of AU activation level significantly increases as activation level goes up. 1.0 being the highest.
c) People recognize some expressions at a lower activation level.
d) Females generally perceive emotions in a wider variety than males.

Chapter 6
CONCLUSION

One of the most important advantages of using BlendShapes is that they provide a high level of control and flexibility in the animation process. Because the targets are unrelated, the artist can easily adjust the weighting values to achieve a variety of expressions. This allows for the creation of complex and subtle facial movements that would be difficult or impossible to achieve using other methods. Furthermore, the study sheds light on how Bangladeshi people perceive facial expressions, as well as the potential applications of BlendShapes in creating realistic digital avatars. The findings of this study could be useful in a variety of fields, including computer graphics, virtual reality, and gaming, where realistic facial expressions and emotions are critical for creating engaging experiences.

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FINAL YEAR PROJECT REPORT FACIAL BLENDSHAPE PERCEPTION STUDIES FOR MOTION CAPTURE AND INTEGRATION WITH INTERACTIVE MEDIA BY SHYKH ANJUM ID: 182-40-527 This Report Presented in Partial Fulfillment of the Requirements for the Degree of Bachelor of Science in Multimedia and Creative Technology Supervised By Mr. Arif Ahmed Associate Professor Department of Multimedia and Creative Technology Daffodil International University DAFFODIL INTERNATIONAL UNIVERSITY DHAKA, BANGLADESH MARCH 2023 APPROVAL This Project titled "Facial Blendshape Studies For Motion Capture And Integration With Interactive Media", submitted by Shykh Anjum to the Department of Multimedia and Creative Technology, Daffodil International University, has been accepted as satisfactory for the partial fulfillment of the requirements for the degree of B.Sc. in Multimedia and Creative Technology and approved as to its style and contents. The presentation has been held on 04 March, 2023. BOARD OF EXAMINERS Chairman Md. Salah Uddin Assistant Professor & Head (In-Charge) Department of Multimedia and Creative Technology Faculty of Science & Information Technology Daffodil International University Internal Examiner Arif Ahmed Associate Professor Department of Multimedia and Creative Technology Faculty of Science & Information Technology Daffodil International University Internal Examiner Mizanur Rahman Assistant Professor Department of Multimedia and Creative Technology Faculty of Science & Information Technology Daffodil International University External Examiner Abul Fatah Md. Baligur Rahman Project Director Digital Entrepreneurship and Innovation Ecosystem Development Project Bangladesh Hi-Tech Park Authority (BHTPA) Information and Communication Technology (ICT) Division Ministry of Posts, Telecommunications and Information Technology DECLARATION I hereby declare that this project has been done by me under the supervision of Mr. Arif Ahmed, Associate Professor, Department of MCT Daffodil International University. I also declare that neither this project nor any part of this project has been submitted elsewhere for award of any degree or diploma. Supervised by: Mr. Arif Ahmed Associate Professor Department of MCT Daffodil International University Submitted by: Shykh Anjum ID: 182-40-527 Department of MCT Daffodil International University ACKNOWLEDGEMENT Without the support and help of numerous people, this endeavor would not have been feasible. My supervisor, Mr. Arif Ahmed sir, has my sincere gratitude for his confidence in me. His constant encouragement and guidance allowed me to work hard to finish this assignment that I initially thought would be challenging for me to accomplish. I also want to express my gratitude to the entire faculty of the Department of Multimedia and Creative Technologies who have worked really hard to continuously support my academic progress throughout this degree. They went above and beyond to deliver the finest education possible despite all the constraints they had to deal with during the COVID-19 pandemic. My parents have always supported me no matter what, and I'm incredibly grateful to them. Without their ongoing assistance, I might not be able to remain standing here. I could not have completed this journey without the assistance of my friends, both inside and outside of the department. They are all incredible people, and I am glad to have them in my life. Finally, I would like to express my appreciation and gratitude to my wife. She is the foundation on which I'm able to stand. My academics, this dissertation, or the stability of my life wouldn't have been possible without her unwavering support. Thank you. ABSTRACT This research paper investigates the perception of BlendShapes through Action Unit activation by Bangladeshi individuals. The study aims to identify the level of understanding and recognition of BlendShapes, which are commonly used in the animation and gaming industry for facial expression and emotion representation. To achieve this, participants are presented with a series of facial expressions created using BlendShapes and asked to identify the emotion being portrayed. Furthermore, a real-time facial capture setup is designed using these BlendShapes to capture facial expressions and emotions in real-time. The study provides insights into the perception of facial expressions by Bangladeshi individuals and the potential applications of BlendShapes in creating realistic digital avatars. The findings of this research could be useful in various fields, such as computer graphics, virtual reality, and gaming industries, where realistic facial expressions and emotions are crucial for creating engaging experiences. TABLE OF CONTENTS CONTENTS APPROVAL DECLARATION ACKNOWLEDGEMENT ABSTRACT GLOSSARY PAGE 1 2 3 4 12 CHAPTER 1 : INTRODUCTION 1.1 Introduction CHAPTER 2 : REVIEW OF RELATED LITERATURE 2.1 Modeling a Face for Facial Animation 2.2 Face Modelling and Edgeflow 2.3 Facial BlendShapes 2.4 Facial Action Coding System & Action Units 2.5 Facial Expressions 2.6 Facial Motion Capture in Industry 2.6.1 Facial Motion Capture in Films 2.6.2 Facial Motion Capture in Games 2.6.3 Facial Motion Capture in Online Platforms 2.7 Psychological Factors Behind Different Facial Expressions 1-3 1 4-25 4 6 9 12 15 18-24 18 22 23 25 CHAPTER 3: BLENDSHAPE PERCEPTION ANALYSIS 3.1 Survey of Perceptual Analysis 3.2 Charts, Calculations and ANOVA Interaction CHAPTER 4: METHODS 4.1 Software Used in this Project 4.2 Sculpting 4.3 Retopology 4.4 Making BlendShapes 4.5 Virtual Avatar in Unity 4.5.1 Mixamo to Unity: 4.5.2 Unity Animation & BlendTree 4.5.3 Setting ARKit in Unity CHAPTER 5: DISCUSSION CHAPTER 6: CONCLUSION REFERENCES 26-50 27 48 51-80 52 53 57 60 67-80 67 70 74 81-85 86 87 LIST OF FIGURES FIGURES PAGE Figure 2.1 A human mouth in the four basic poses Figure 2.2.1 Proper Edgeflow of the face by artist Miguel Miranda Figure 2.2.2 Planning the Facial Retopology by Julien Kaspar Figure 2.2.3 Facial Retopology by Julien Kaspar (Blender Studio) Figure 2.3.1 Examples of BlendShapes Figure 2.3.2 Screenshot of a portion of the blendshape slider interface Figure 2.5.1 Facial expressions beneath skin Figure 2.5.2 Facial expression: Fear Figure 2.5.3 Facial Expression: Fear Figure 2.6.1.i Andy Serkis as Gollum in The Lord of the Rings (2001) Figure 2.6.1.ii Zoe Saldana as Neytiri in Avatar 1 (2009) Figure 2.6.1.iii Benedict Cumberbatch as Smaug in The Hobbit (2013) Figure 2.6.1.iv Andy Serkis and Jason Clarke as Caesar and Malcolm in Dawn of the Planet of the Apes (2014) Figure 2.6.1.v Josh Brolin as Thanos in Avenger Endgame (2019) Figure 2.6.1.vi Sam Worthington and Zoe Saldana as Jake Sully and Neytiri in Avatar The Way of Water (2022) Figure 2.6.2 Senua hellblade Figure 2.6.3.i CodeMiko Figure 2.6.3.ii CodeMiko Facial

GLOSSARY TERM DEFINITION BlendShape Activation Level ANOVA AU Digital Human EdgeFlow FACS Hierarchy Motion Capture Retopology Transforming the target object shapes into a blend of the base object shapes. Intensity of changes in Blendshape Analysis of variance, statistical technique for dividing observed variance data into its various components. The basic operations of a muscle or group of muscles that ultimately creates expressions SS-Sum of Squares; df- degree of Freedom; MS- Mean Square; F-ratio of two variances; P value- significant factors; .F crit- Critical value of F A virtual avatar capable of displaying a wide variety of human body language Making sure that edges conform to the model's geometry and curvature Facial Action Coding System, a system to classify human facial motions according to how they appear on the face The way GameObjects are sorted in respect to their relations in a scene of a game engine. Process of recording live-objects movement. Modeling procedure where the polygonal mesh of an item is changed or reconstructed to produce a cleaner structure. Chapter 1 INTRODUCTION 1.1 Introduction The term "Metaverse" has become one of the most popular buzzwords in recent years. Although the idea of a virtual world is nothing new, it has lately gained popularity as a result of the advancement of VR technology. What, though, is the "Metaverse" in reality? It appears to be a preferred name-dropping among businesses like Facebook, Google, and NVIDIA. The actual technology behind the metaverse, however, and the things that are conceivable with it, are considerably more competent than what these billion-dollar businesses are letting on at the moment. A truly virtual environment must be able to recognize and depict human emotions in real time rather than merely allowing some low-poly game characters to just walk around. Because in a world where we are unable to communicate via our facial emotions, our human brains will never fully emerge. Face perception is a particularly active topic of research in psychology since it has been demonstrated that people view faces differently than other objects (Farah et al., 1998). According to research by Schwaninger et al., rather than being processed holistically, faces are also analyzed in terms of their individual parts and how they are arranged (Schwaninger et al., 2006). Emotion is a major psychological component that influences facial expressions. Emotions are internal states associated with physiological arousal and behavioral changes, such as changes in facial expressions. When a person is pleased, they may grin, and when they are upset, they may frown. These facial expressions are regarded to be universal and are often recognized by people from all cultures. Cognition, or the processes of thinking and reasoning, is another major psychological aspect underlying facial expressions. Even when we are not consciously aware of it, our ideas and beliefs can impact the facial expressions we create. For example, if a person is thinking about something that makes them happy, they may involuntarily grin without realizing it. In general, the psychological explanations for facial expressions are intricate and multifaceted, and they may involve emotions, ideas, and cultural context. These variables can affect how people express themselves facially, as well as how they are affected by others' emotions.

There were further studies that employed information about individual action units to construct synthetic phrases. The detection of an expression was achieved by gradually activating certain action units (Yu et al., 2012). Reverse engineering expressions based on perceptual relevance aided in enhanced facial recognition in artificial faces (Chen et al., 2018). There is ample data to demonstrate that action units alone have a perceptually substantial influence on emotion classification. However, it is uncertain if certain action units are more noticeable than others because they are connected with a specific emotional expression. The idea is to provide people access to real-time face capturing technology. Real-time face tracking was previously impossible, despite the fact that face tracking technology is utilized in movies like The Lord of the Rings, Pirates of the Caribbean, and Avatar. This has changed because of the incredible advancements in GPU technology. Any character may be made to come to life in real time utilizing Apple's ARKit or a comparable face tracking program with the necessary Blendshape data. Any spectrum of human emotions may be simulated using those Blendshape data, which can be then sent to a game engine like Unity, Unreal or in any virtual reality platform like the Metaverse. Live face capture is a method used in the creation of movies and video games to record the movements and facial expressions of actors in real-time. This makes it possible to create character animations that are incredibly precise and lifelike, especially when it comes to their facial emotions. In order to follow the actor's facial movements and expressions during live face capture, sophisticated tools like depth sensors and infrared cameras are frequently used. The actor's performance may then be instantly transferred into the virtual environment using this data, which is then utilized to drive the animation of the digital character in real time. However, such technology is expensive and necessitates a plethora of specialized devices and software that are out of reach for the mainstream population. This is where predetermined facial-blendshape and Action Unit (AU) come in, which can track a human face's movement using LIDAR technology and replicate almost the same outcome. In this paper, I'll explore the possibility of employing blendshapes (morph targets) to record real-time face expression and establish a standard for affordable character facial animation that can be used in any virtual environment. The motivation behind that is to establish a standard derivation in blendshape perception for Digital humans in Bangladesh. Chapter 2 REVIEW OF RELATED LITERATURE 2.1 Modeling a Face for Facial Animation The first step in preparing any character for facial animation is to accurately model the face. By accurately, I mean modeling the face in a way that allows the face to be rigged to follow the natural movement of a human face. Edgeflow is a critical component that must be maintained in order to do this, because it determines how smoothly and naturally the surface of the face will deform when the model is animated. Edgeflow refers to the way that the edges of the polygons in a 3D model are arranged and connected to each other. A model with good Edgeflow will have edges that follow the natural contours and wrinkles of the face, allowing the model to deform smoothly and naturally when it is animated. This is important because it helps to create a more realistic and expressive animation. On the other hand, a model with poor Edgeflow may have edges that do not follow the natural contours of the face, resulting in unnatural or distorted deformations when the model is animated. This can lead to a less realistic and less expressive animation. In the book Stop Staring: Facial Modeling and Animation Done Right (Osipa, 2010) the author Jason Osipa describes the ideal way to model a face and its facial features to be ready for animation. He described the lip sync part as - "When teased apart properly, the lip sync portion of facial animation is the easiest to understand because it's the simplest. You see, people's mouths don't do that much during speech. Things like smiles and frowns and all sorts of neat gooey faces are cool, and we'll get to them later, but for now we're just talking sync. Plain old speech. Deadpan and emotionless and, well, boring, is where our base will be. Now, you're probably thinking, "Hey! My face can do all sorts of stuff! I don't want to create boring animation!" Well, you're right on both counts: Your face can do all sorts of things, and who really wants to do boring animation? Nobody! For the basics, however, this is a case of learning to walk before you can run. For now, we're not going to complicate it. If we jumped right into a world with hundreds or even thousands of verbal and emotional poses (which is how they do it in the movies), we'd never get anywhere. So, to make sure you're ready for the advanced hands-on work later, we're focusing on the most basic concept now: bare-bones lip sync. When dealing with the essentials of lip sync and studying people, there are just two basic motions. The mouth goes Open/Closed, and it goes Wide/Narrow, as illustrated in below figure. (Osipa, 2010) Figure 2.1 A human mouth in the four basic poses 2.2 Face Modelling and Edgeflow Edgeflow is an important consideration in face modeling because it affects the overall quality and realism of the model. Edgeflow refers to the way that the edges of a 3D model are arranged and connected, and it plays a role in how the model deforms and moves during animation. Figure 2.2.1 Proper Edgeflow of the face by artist Miguel Miranda Good edgeflow is important for a number of reasons: 1. Smooth deformation: Good edgeflow helps to ensure that the mesh deforms smoothly when it is animated, which is particularly important for facial animation. This can help to create more realistic and expressive facial movements. 2. Efficient topology: Good edgeflow can help to make the topology of the mesh more efficient, which can make it easier to work with and can reduce the risk of errors or problems during the modeling process. 3. Better shading: Good edgeflow can help to ensure that the shading of the mesh is smooth and consistent, which can improve the overall appearance of the model. When a model is animated, good edgeflow ensures that it deforms smoothly and naturally without causing unwanted artifacts such as pinching or stretching. This is critical for facial animation since the face is one of the body's most expressive and dynamic organs, and viewers can detect even tiny variations. Figure 2.2.2 Planning the Facial Retopology by Julien Kaspar To achieve good edgeflow in a face model, it is important to carefully plan the placement and connectivity of the edges, taking into account the movements and deformations that the model will need to perform. This may involve adding or removing edges, or adjusting the placement of existing edges. Figure 2.2.3 Facial Retopology by Julien Kaspar (Blender Studio) Edgeflow is a significant concern in face modeling since it has a large impact on the final model's quality and realism. You may produce a model that deforms smoothly and organically by carefully designing and tweaking the edgeflow of a face model, which is vital for generating realistic and expressive facial animations. 2.3 Facial BlendShapes BlendShapes, also known as morph targets or mesh deformation, are a 3D computer graphics technique for making tiny changes to the shape of a mesh. This enables a more fluid transition between forms, resulting in more realistic and fluid animations. This method is used in 3D computer graphics to generate smooth and seamless transitions between different face expressions or forms. It's widely utilized in animation and film production to

generate realistic and accurate character motions, especially for face expressions. In the research paper "Practice and Theory of Blendshape Facial Models", we get the definition: BlendShapes are linear facial models in which the individual basis vectors are not orthogonal but instead represent individual facial expressions. The individual basis vectors have been referred to as blendshape targets and morph targets, or (confusingly) as shapes or blendshapes. The corresponding weights are often called sliders, since this is how they appear in the user interface (Lewis et al., 2014) To create a blendshape animation, the artist first selects the rest pose mesh and sets it as the base for the animation. They then create the various targets that they want to use in the animation. Each target is created by making small changes to the vertices of the mesh, either by moving them manually or using a sculpting tool. Once the targets have been created, the artist can then use them to animate the mesh. This is done by blending the different targets together, using a value known as the "blend weight" to control the amount of each target that is used in the final shape of the mesh. By adjusting the blend weights over time, the artist can create smooth transitions between different shapes, resulting in realistic and fluid animations. BlendShapes have become an essential tool in the world of 3D animation, allowing artists to create more realistic and expressive characters. They are widely used in a variety of applications, including video games, movies, and television shows. One of the key advantages of blendshapes is their ability to create realistic facial expressions. By using a series of targets that represent different facial expressions, artists can create characters that can smile, frown, blink, and make other expressions with a high degree of realism. This makes them especially useful for creating characters that need to express a wide range of emotions, such as human or animal characters. Figure 2.3.1 Examples of BlendShapes Another advantage of blendshapes is their flexibility. Because they are based on small changes to the rest pose mesh, they can be easily modified and adjusted to create a wide range of shapes and animations. This allows artists to experiment and try out different ideas, resulting in more creative and dynamic animations. Figure 2.3.2 Screenshot of a portion of the blendshape slider interface 2.4 Facial Action Coding System & Action Units The Facial Action Coding System (FACS) is a collection of facial muscle movements that correspond to the expression of an emotion. Carl-Herman Hjortsjö invented it in 1970 with 23 facial motion units, and Paul Ekman and Wallace Friesen improved on it. The FACS was initially published in 1978, however it was significantly revised in 2002. Table of Action Units and related Muscles. Action Unit Description Facial Muscle 1 Inner Brow Raiser *Frontalis, pars medialis* 2 Outer Brow Raiser (*Frontalis, pars lateralis* 4 Brow Lowerer *Depressor Glabellae, Depressor Supercilli, Currugator* 5 Upper Lid Raiser *Levator palpebrae superioris* 6 Cheek Raiser *Orbicularis oculi, pars orbitalis* 7 Lid Tightener *Orbicularis oculi, pars palpebralis* 9 Nose Wrinkler *Levator labii superioris alaeque nasi* 10 Upper Lip Raiser * Levator Labii Superioris, Caput infraorbitalis* 11 Nasolabial Deepener *Zygomatic Minor* 12 Lip Corner Puller *Zygomatic Major* 13 Cheek Puffer *Levator anguli oris (Caninus)* 14 Dimpler *Buccinator* Action Unit Description Facial Muscle 15 Lip Corner Depressor *Depressor anguli oris (Triangularis)* 16 (with AU25) Lower Lip Depressor *Depressor labii inferioris* 17 Chin Raiser *Mentalis* 18 Lip Puckerer *Incisivii labii superioris* and *Incisivii labii inferioris* 20 Lip stretcher *Risorius * 22 Lip Funneler *Orbicularis oris* 23 Lip Tightener *Orbicularis oris* 24 Lip Pressor *Orbicularis oris* 25 Lips part *Depressor Labii, Relaxation of Mentalis (AU17), Orbicularis Oris* 26 Jaw Drop *Masetter; Temporal and Internal Pterygoid *relaxed 27 Mouth Stretch *Pterygoids, Digastric* 28 Lip Suck *Orbicularis oris* 41 Lid droop Relaxation of *Levator Palpebrae Superioris* 42 Slit *Orbicularis oculi* 43 Eyes Closed Relaxation of *Levator Palpebrae Superioris* Action Unit Description Facial Muscle 44 Squint *Orbicularis oculi, pars palpebralis* 45 Blink Relaxation of *Levator Palpebrae and Contraction of Orbicularis Oculi, Pars Palpebralis.* 46 Wink *Levator palpebrae superioris; Orbicularis oculi, pars palpebralis* 2.5 Facial Expressions Author Uldis Zarins provided a thorough explanation of facial anatomy in his book Anatomy of Facial Expressions (Zarins, 2014) , highlighting the connections between the muscles in our faces that are located beneath the skin. As you can see, the muscles in our face are all interrelated, making it difficult to move one muscle without also moving others. Figure 2.5.1 Facial expressions beneath skin The system is based on the idea that specific facial muscles produce specific facial movements, and that these movements can be used to identify emotions or other internal states. The movements are organized into a set of action units (AUs), which are numbered and defined according to the specific muscles and movements involved. For example, AU 1 corresponds to inner brow raise, AU 2 corresponds to outer brow raise, and so on. Figure 2.5.2 Facial expression: Fear Figure 2.5.3 Facial Expression: Fear 2.6 Facial Motion Capture in Industry FACS has been widely used in research on facial expression and emotion, and it has also been used as a tool for creating realistic facial animations in film and video games. In live face tracking, FACS can be used to analyze and interpret real-time facial movements in order to generate corresponding facial animations or to identify emotions or other internal states. 2.6.1 Facial Motion Capture in Films The character Gollum in the Lord of the Rings trilogy is one example of how face tracking has been used in cinema. Andy Serkis played Gollum in the movie utilizing motion capture, with his facial emotions recorded using a number of techniques, including face tracking. The resultant facial movements were then utilized to produce Gollum's computer character model, from which the final character animation in the movie was generated. Figure 2.6.1.i Andy Serkis as Gollum in The Lord of the Rings (2001) Facial tracking has been employed in a number of big motion pictures to produce realistic facial animations for human and non-human creatures. Other films that have incorporated face tracking include The Hobbit series, Avatar, The Avengers, The Pirates of the Caribbean series, and The Planet of the Apes series. Facial tracking was utilized in these films to produce accurate facial animations for both human and non-human characters, as well as digital doubles of performers for use in character animation. Figure 2.6.1.ii Zoe Saldana as Neytiri in Avatar 1 (2009) Figure 2.6.1.iii Benedict Cumberbatch as Smaug in The Hobbit (2013) Figure 2.6.1.iv Andy Serkis and Jason Clarke as Caesar and Malcolm in Dawn of the Planet of the Apes (2014) Figure 2.6.1.v Josh Brolin as Thanos in Avenger Endgame (2019) Avatar 2 by James Cameron introduces a new technology that replaces the FACS system with the Anatomically Plausible Facial System, or APFS. "A FACS system simply simulates an external face and has extremely limited capabilities... It is only an emotional mechanism that codes expressions. FACS does not encode communication, yet much of what we do is dialogue." While FACS may accurately capture an isolated emotion, there is no information on how to transition between poses. "You end up having to sort of guess," reveals Joe Letteri, Avatar's VFX director and four-time Oscar winner. (Seymour M., 2022) Figure 2.6.1.vi Sam Worthington and Zoe Saldana as Jake Sully and Neytiri in Avatar

The Way of Water (2022) 2.6.2 Facial Motion Capture in Games The Ninja Theory team created a facial scan of Melina Juergens, the actress who portrays Senua, the main character in the video game Hellblade: Senua's Sacrifice, using photogrammetry, a technique for determining depth from images. In order to track the actor's face and bodily movements as well as the filmer's position in 3D space, the team later developed Hydra, a prototype camera system with several GoPros and replaceable lenses. A camera and a cricket helmet were used in another prototype to record faces. The characters BlendShape then received this information using the Unreal engine. To describe how experimental the technology still is, Ninja Theory's Chief Creative Director Tameem Antoniades said, "It was just unproven at the time, and we were the guinea pigs. But it worked beautifully. The detail was just incredible." (Summers N., 2017) Figure 2.6.2 Senua hellblade 2.6.3 Facial Motion Capture in Online Platforms A live face tracking Vtuber is a virtual character that uses real-time facial tracking to generate facial animations in response to the movements and expressions of a human performer. The process typically works as follows: 1. The performer wears a headset with a camera or other sensor that is used to capture their facial movements and expressions. 2. The camera or sensor feeds live video of the performer's face to a computer running facial tracking software. 3. The facial tracking software analyzes the movements and expressions of the performer's face in real time, and generates corresponding facial animations for the Vtuber character. 4. The facial animations are combined with a 3D model of the Vtuber character and rendered in real time, creating a live video feed of the Vtuber character with facial movements that match those of the performer. 5. The live video feed of the Vtuber character is then streamed online, allowing viewers to watch and interact with the character in real time. Figure 2.6.3.i CodeMiko The twitch streamer CodeMiko is one of the most well-known Vtubers that uses facial tracking for her virtual avatar. She is among the first persons to use online streaming services in this manner. The unique aspect of CodeMiko is that her creation utilizing the Unreal engine, as well as her interactions with other people, are becoming mainstream and no longer feel strange. CodeMiko is a pioneer in the virtual representation in this sector, whether it be VTube, VRChat, or the Metaverse. Youna Kang, the person behind CodeMiko's both technical and real-life selves, addressed Inverse Magazine about the challenges she faces, saying, "wearing everything was the hardest part, because I would feel like I was being strangled in my suit a lot. If you stream for six hours every single day, the trackers keep hitting the same pressure points. Those trackers would actually start hurting my skin, which becomes really uncomfortable." Figure 2.6.3.ii CodeMiko Facial Expression 2.7 Psychological Factors Behind Different Facial Expressions (Fasel & Luettin, 2003) stated that the causes of facial expressions include mental states (e.g. felt emotions, conviction, and cogitation), verbal communication (e.g. illustrators, listener reactions, and regulators), nonverbal communication (e.g. unfelt emotions, emblems, and social winks), and physiological processes (e.g. manipulators, pain and tiredness). As seen in Figure 2.7, we divide the elements that determine face expressions into social, emotional, and physiological components, as well as expressive personality. Figure 2.7 Factors that influence facial expressions Thus, it is evident that no matter how skilled an animator is, they will never be able to precisely duplicate the intricacy of expression and feeling. Facial Motion Capture is therefore extremely important in the virtual reality environment in order to communicate emotion. Chapter 3 BLENDSHAPE PERCEPTION ANALYSIS This chapter is heavily influenced by a research done in Trinity College Dublin, which was published in the 13th ACM SIGGRAPH Conference in 2020. The research paper is titled Investigating perceptually based models to predict importance of facial blendshapes (Carrigan et al., 2020). The researchers chose a neutral face and 9 BlendShapes to better understand the perception of the viewers of digital humans. They wanted to see which activation level is appropriate for which Action Units. In the original research, the researcher took 20 participants and showed them the chosen Action Units in various activation levels, and the participants had to choose the AU they perceive to be truly able to convey the said Emotion. The participants were predominantly White and of European ethnicity. I re-examined the same AU perception experiment but with Bangladeshi Participants. Here are the 9 AU that was selected: AUs which are important for emotion: AU 2: Right Eyebrow Up (Outer Brow Raiser) AU 4: Frown (Brow Lowerer) AU 5: Eye Open (Upper Lid Raiser) AU 12: Smile (Lip Corner Puller) AU 15: Mouth Frown (Lip Corner Depressor) AU 26: Jaw Drop AU 38: Nostril Dilator AUs which are important for speech: AU 18: Lip Pucker AU 34: Cheeks Puffed A neutral Face was shown to all participants, with 5 activation levels of 0.2 , 0.4 , 0.6 , 0.8 , and 1.0 for each of them, where 0.2 being the lowest activation and 1.0 being the highest activation. 3.1 Survey of Perceptual Analysis I have conducted an online survey where 54 participants participated and answered the survey questions. I had two variables while conducting the survey, age and gender. The motivation of this survey is to replicate the original research as closely as possible. But as this participant pool only consists of 1 race, the variable race is omitted. All the options were randomized, so that participants don't get biased. Figure 3.1.1 Percentage of Highest Education Level of Participants Figure 3.1.2 Percentage of Gender Dividation of Participants Figure 3.1.3 Age Group Figure 3.1.4 Familiarity with VR platforms Figure 3.1.5 Neutral Face The Neutral Face is the one that was determined as a face with no apparent expression. All the AU has to be compared with this face. AU 2: Right Eyebrow Up: Figure 3.1.6 AU 2: Right Eyebrow Up (Outer Brow Raiser) Survey Result: Figure 3.1.7 Percentage of AU activation level Figure 3.1.8 Percentage of AU activation level: Male - Female ratio AU 4: Frown (Brow Lowerer) Figure 3.1.9 AU 4: Frown (Brow Lowerer) Survey Result: Figure 3.1.10 Percentage of AU activation level Figure 3.1.11 Percentage of AU activation level: Male - Female ratio AU 5: Eye Open Figure 3.1.12 AU 5: Eye Open (Upper Lid Raiser) Survey Result: Figure 3.1.13 Percentage of AU activation level Figure 3.1.14 Percentage of AU activation level: Male - Female ratio AU 12: Smile Figure 3.1.15 AU 12: Smile (Lip Corner Puller) Survey Result: Figure 3.1.16 Percentage of AU activation level Figure 3.1.17 Percentage of AU activation level: Male - Female ratio AU 15: Mouth Frown Figure 3.1.18 AU 15: Mouth Frown (Lip Corner Depressor) Survey Result: Figure 3.1.19 Percentage of AU activation level Figure 3.1.20 Percentage of AU activation level: Male - Female ratio AU 26: Jaw Drop Figure 3.1.21 AU 26: Jaw Drop Survey Result: Figure 3.1.22 Percentage of AU activation level Figure 3.1.23 Percentage of AU activation level: Male - Female ratio AU 38: Nostril Dilator Figure 3.1.24 AU 38: Nostril Dilator Survey Result: Figure 3.1.25 Percentage of AU activation level Figure 3.1.26 Percentage of AU activation level: Male - Female ratio AU 18: Lip Pucker Figure 3.1.27 AU 18: Lip Pucker Survey Result: Figure 3.1.28 Percentage of AU activation level Figure 3.1.29 Percentage of AU activation level: Male - Female ratio AU 34: Cheeks Puffed Figure 3.1.30 AU 34: Cheeks Puffed Survey Result: Figure 3.1.31 Percentage of AU activation level Figure 3.1.32

Percentage of AU activation level: Male - Female ratio 3.2 Charts, Calculations and ANOVA Interaction From the Survey, we get a total of 54 Inputs from unique participants. We can analyze those data for better understanding the trend of perception. Table of total number of activation par action unit AU 2 AU 4 AU 5 AU 12 AU 15 AU 26 AU 38 AU 18 AU 34 0.2 10 3 4 2 3 2 2 1 5 0.4 8 4 16 3 12 17 6 6 4 0.6 6 7 13 13 15 12 6 5 17 0.8 8 8 5 14 19 13 10 12 17 1.0 22 32 16 22 5 10 30 30 11 Sum 54 54 54 54 54 54 54 54 54 From Our survey, we randomly chose 11 participants from each group of Male(15-25), Male (26-35) , Female (15-25) and Female (26-35) to be used in two-way ANOVA interaction. Anova Interactions are used to determine whether two or more factors have any effect on the result produced. We have to take 3 null hypotheses first, and if the value of F-distribution is greater than F-critical value, we reject the null hypothesis. Anova Interaction between Gender and activation level of 9 Action Units: Hypothesis 1: Gender has no effect Hypothesis 2: Different Activation level has no effect Hypothesis 3: Gender and activation together has no effect. Table of Two-way ANOVA between activation level and gender Source of Variation SS df MS F P-value F crit Sample 0.00 1.00 0.00 0.03 0.87 3.87 Columns 2.60 8.00 0.33 5.65 0.00 1.96 Interaction 0.42 8.00 0.05 0.90 0.51 1.96 Within 21.76 378.00 0.06 Total 24.79 395.00 As we can see, only the Activation Level (columns) has an effect on the result. Also, the p-value is less than the given significant level of .05. So we can also reject HYpothesis 2 from here. Anova Interaction between Gender and Age: Hypothesis 1: Gender has no effect Hypothesis 2: Age has no effect Hypothesis 3: Gender and Age together has no effect. Table of Two-way ANOVA between gender and age Source of Variation SS df MS F P-value F crit Sample 0.00 1.00 0.00 0.01 0.91 4.08 Columns 0.01 1.00 0.01 0.74 0.40 4.08 Interaction 0.01 1.00 0.01 0.74 0.40 4.08 Within 0.55 40.00 0.01 Total 0.57 43 Here we can see that none of the F- values is greater than F-critical value. So, all of the null hypotheses are true. So, Gender, Age or their combination has no effect on the perception of BlendShapes. Chapter 4 METHODS We now have a clear direction for our work from the previous chapter. We must follow the guidelines provided and experiment as needed to reach our goals. These are the four steps we have to take in order to achieve that: 1. The face must be sculpted and retopologies using a reference image. The next step is to construct and rename all of the BlendShapes models that we want to see in the finished model, in this case, all 52 of them. 2. Importing the BlendShapes into Unity Engine and configuring it to make the most use of the data from those BlendShapes in order to prepare it for live face tracking. 3. Creating a basic third-person character, inserting unique animation, and integrating the face and body to make it come to life. 4. Setting up the scene in Unity and making the necessary adjustments to the lighting, volume, and other parameters. 4.1 Software Used in this Project Table of Software's used Function Software used Format Sculpting Zbrush .stl to .obj Retopology Autodesk Maya .obj BlendShapes Blender .obj to. fbx Face Track Apple ARKit C# Motion Capture Mixamo .fbx for Unity Game Engine Unity .fbx , C# Data Analysis MS Excel .xlsx 4.2 Sculpting I chose Zbrush as my primary sculpting software. The reason to choose ZBrush is, apart from being an industry standard software. The Base model was provided as a sample model in the Apple ARKit package, but for usability purposes, had to be shaped and tweaked. For that, I followed below steps 1. Import the reference photos: In ZBrush, go to the "Import" tab and import both the front and side reference photos. Figure 4.2.1 Head Reference Figure 4.2.2 Setting Front+Side Reference 2. Create a base mesh: Use the DynaMesh or ZSpheres tools to create a base mesh that roughly matches the shape of the face in the reference photos. Figure 4.2.3 Dynamesh for low-res Sculpt 3. Adjust the base mesh: Use the Move, Scale, and Rotate tools to adjust the base mesh so that it more closely matches the shape of the face in the reference photos. 4. Add details: Use sculpting tools such as the Clay Buildup, DamStandard, and Smooth brushes to add details to the face, such as wrinkles, pores, and facial hair. Use the reference photos as a guide to help you get the proportions and details right. Figure 4.2.4 ZBrush brushes 5. Refine the sculpt: Continue to refine the sculpt using a variety of sculpting tools and techniques. Pay attention to the overall shape of the face, as well as the smaller details. Figure 4.2.5 ZRemesher for Higher polygon 6. Export the model: When you are finished sculpting, export the model as an .obj file or other suitable format for use in other software. Figure 4.2.6 Finalized Version of the sample model 4.3 Retopology My chosen tool for retopologizing the model was Autodesk Maya. The Quad Draw mode in the Modelling ToolKit in Maya is a powerful retopology tool. Edgeflow maintenance is made simpler by using this tool. To retopology in Maya using the Quad Draw modeling toolkit, I will follow these steps: 1. First, I will select the base mesh that I want to retopologize in the Modeling tab. Then I will make the model a Live Object, so it can't be selected. 2. Next, I will enter quad draw mode by clicking the "Enter Quad Draw" button in the Quad Draw tab. Figure 4.3.1 Maya Retopology 3. Using the Quad Draw tools, such as the Quad Draw brush and the Loop and Ring tools, I will create a new topology for the base mesh. This will involve drawing a series of quads over the surface of the base mesh, following the contours and details of the model. 4. As I work, I will adjust the topology as needed, adding or deleting quads as needed to refine the mesh. Figure 4.3.2 Live Object & Quad Draw 5. When I am happy with the topology, I will use the "Project All" command in the Quad Draw tab to project the topology onto the base mesh, creating a new mesh with the desired topology. Figure 4.3.3 More Edge Loops! 6. To clean up the mesh, I will use tools such as the Merge and Weld tools to remove any unnecessary vertices or edges. Then I sub-divided the mesh, ready to be exported as Fbx format. Since Edgeflow has an impact on the model's overall quality and realism, it is crucial to take it into account while modeling faces. Edgeflow is the arrangement and connection of a 3D model's edges, and it affects how the model deforms and moves during animation. When a model is animated, a proper Edgeflow makes sure that it deforms smoothly and organically without producing unfavorable artifacts like pinching or stretching. This is crucial for facial animation since the face is one of the body's most expressive and dynamic organs, and viewers may pick up on even minor deviations. Figure 4.3.4 Facial Edgeflow in Maya 4.4 Making BlendShapes Figure 4.4.1 Shape Key (BlendShapes) Editor in Blender BlendShapes, a technology that has proven indispensable in the realm of 3D animation, enable artists to produce more emotive and lifelike figures. They are extensively utilized in a wide range of media, including motion pictures, television shows, and video games. The capacity of BlendShapes to produce lifelike face expressions is one of its main benefits. The adaptability of BlendShapes is another benefit. They are easily adaptable and may be changed to produce a wide variety of forms and animations since they are dependent on minor adjustments to the rest posture mesh. This enables animators to explore and test out various concepts, leading to more original and dynamic animations. I chose Blender as my preferred software, because of the robustness it

offers in terms of creating Shape Keys (BlendShapes are called Shape Keys in Blender). The sample BlendShapes were provided by Apple ARKit, which I tweaked and shaped as needed. Here is A step by step guide for making BlendShapes in Blender: 1. First, I will start with a base mesh of the face that includes all of the main features of the face, such as the eyes, nose, mouth, and ears. Figure 4.4.2 Landmark Placement(Object those should move with face ie: brow) 2. For each blendshape I want to create, I will create a new object in Blender. This object will be used to define the shape of the blendshape. 3. Using modeling tools such as the Extrude, Scale, and Loop Cut tools, I will modify the shape of the blendshape object to define the shape of the blendshape. 4. In the Object Data properties panel, I will click the "Add Shape Key" button to add a shape key to the base mesh. 5. In the Shape Keys properties panel, I will click the "Add Driver" button and select the blendshape object as the driver. This will link the shape of the blendshape object to the shape key. Figure 4.4.3 All Required BlendShapes 6. I will repeat this process for each blendshape I want to create, creating a new object and shape key for each blendshape. Figure 4.4.4 Base Mesh Figure 4.4.5 RightBrow Figure 4.4.6 Left Brow Figure 4.4.7 Eye Squint Figure 4.4.8 Eye Look Right Figure 4.4.9 BlendShapes in Making 7. Once I have created all of the blendshapes, I will test them by adjusting the value of each shape key in the Shape Keys properties panel. This will allow me to see how the blendshapes deform the base mesh. Figure 4.4.10 Side by Side 4.5 Virtual Avatar in Unity Unity is a 2D and 3D game engine that was first released in 2005. It was created by Unity Technologies to provide more creators access to game production tools, which was an unique idea at the time. The engine has altered and grown substantially during its lengthy life, keeping up with the most recent methods and innovations. I picked Unity over Unreal Engine for live tracking for two reasons: first, it is less GPU intensive, and Unity is easier to use. 4.5.1 Mixamo to Unity: After choosing a Body mesh to be attached with the face, I imported the mesh to the Mixamo platform to be rigged. Than I followed below steps- 1. Go to the Mixamo website and sign in. Figure 4.5.1.i Getting Character rigged in Mixamo 2. Browse for the animation you want to use and click on it to select it. 3. Click on the "Download" button and choose the "FBX for Unity" option from the dropdown menu. Figure 4.5.1.ii Downloading preferred animation, Without Skin, FBX for Unity 4. Save the downloaded FBX file to a location on your computer. 5. In Unity, go to "Assets > Import Package > Custom Package" and select the downloaded FBX file. 6. In the Import Unity Package window, click on the "Import" button to import the animation into your Unity project. Figure 4.5.1.iii The Body is Rigged in Mixamo 7. Drag the animation file from the "Project" window to the object in your scene to apply the animation. Figure 4.5.1.iv The helmet is a child of the body 4.5.2 Unity Animation & BlendTree Figure 4.5.2.i Animation Motions from Mixamo Figure 4.5.2.ii All animations has to Rigged Humanoid, with Avatar source from the Body To set up a blend tree animation in Unity for a character, we can follow these steps: 1. In the "Project" window, create a new "Animator Controller" and name it. Figure 4.5.2.iii Unity new input system 2. Double-click on the new Animator Controller to open it in the Animator window. Figure 4.5.2.iv Components of the character 3. In the Animator window, right-click on the blank area and select "Create State > Empty" to create a new state. Figure 4.5.2.v Animator window with BlendTree 4. Right-click on the new state and select "Make Transition" to create a transition from the default state to the new state. Figure 4.5.2.vi Animation state transitions needs to have parameters to functions 5. In the "Inspector" window, click on the "Motion" field of the new state and select the animation clip that you want to use in the blend tree. 6. Right-click on the new state again and select "Create State > Blend Tree" to create a blend tree state. 7. In the "Inspector" window, set the "Blend Type" to "1D" and click on the "+" button to add animation clips to the blend tree. 8. Set the parameters that will control the blend tree, such as speed or direction. Figure 4.5.2.vii Talk Tree blend tree 9. Connect the blend tree state to the default state with a transition and set the transition conditions based on the blend tree parameters. 10. Drag the Animator Controller onto the object in your scene to apply the blend tree animation. 4.5.3 Setting ARKit in Unity To set up the BlendShape Data Face in Unity, we have to these step 1. Import the face From Blender to Unity. Figure 4.5.3.i Blendshape face from Blender 2. In the hierarchy, we have to make the Face a child of the Head-bone, so that it follows and rotates with the body properly. Figure 4.5.3.ii Scene Hierarchy 3. Download ARKit Live face track from Unity registry, and download Unity face track app on my apple device. Figure 4.5.3.iii ARKit Package in Unity Registry Figure 4.5.3.iv Unity Face Capture app in Apple app store 4. To set up properly, we have to take an Animator component, an ARKit Face Actor component and attach them to the face that have the blendshapes. Figure 4.5.3.v Animator Component for face Figure 4.5.3.vi ARKit Face Actor Component for face, that enables BlendShapes 5. We have to take a Sample Face Mapper and attach it to the Face. This will communicate between the Unity Engine and the Live face tracking app. Figure 4.5.3.vii Head Mapper for face tracking Figure 4.5.3.viii Skull & Head Blendshape drivers 6. In the app, we have to position our face, calibrate the face for tracking and make necessary changes. Figure 4.5.3.ix App Calibration 7. In Unity, we set up the project in specific way: a. Take Recorder in the hierarchy b. TimeLine in the Console Panel c. Connection in the Inspector panel- Creating a server for the app to connect Figure 4.5.3.x Exact way the Unity editor has to be set up for Face tracking 8. Start recording in the Apple device, and the face in Unity should start tracking. Chapter 5 DISCUSSION From the previous chapter, we can come to some certain conclusions about our perceptions of facial blendshapes. In the research paper Investigating perceptually based models to predict importance of facial blendshapes (Carrigan et al., 2020) , the researcher came to three important conclusion: i. ii. Character Sex & Race: There was no main effect of the character Sex. However, we found a main effect of character Race Activation Level: A main effect of Activation Level showed a significant increase in perceived differences as the activation increased, as expected . iii. Action Units: Mouth Open (Jaw Drop), Eyes Open, and Smile Lips Closed appeared to have a higher perceptual effect since the perceived differences were significantly higher when compared to all other AUs . Further interactions showed that Mouth Open was significantly more different than most other shapes . Below is a radar-chart of the average value of each of the 9 Action Units. We can clearly see that Bangladeshi participants also do follow similar perceptions. But the effect is more prominent in mouth frown, than Smile. Figure 5.1 Radar Chart of AU activation We can further breakdown this into Male and Female perceptions by age groups. Figure 5.2 Male and Female 15-25 Figure 5.3 Male and Female 26-35 We can also compare how different age groups of the same Gender perceive emotion. Figure 5.4 Female AU activation by age-group Figure 5.5 Male AU activation by age-group Perception By activation of AU: In the below chart, we can see the range of answers by activation level. Figure 5.6 Activation level variation Here

is the same chart shown as male-female percentage: Figure 5.7 Activation level variation: Male-Female Percentage So, with all these analyzed Data, ANOVA interaction and charts, we can confidently come to these conclusions: i. ii. Participants gender has no real effect on the selection of AU activation level Selection of AU activation level significantly increases as activation level goes up. 1.0 being the highest. iii. iv. People recognize some expressions at a lower activation level. Females generally perceive emotions in a wider variety than males. Chapter 6 CONCLUSION One of the most important advantages of using BlendShapes is that they provide a high level of control and flexibility in the animation process. Because the targets are unrelated, the artist can easily adjust the weighting values to achieve a variety of expressions. This allows for the creation of complex and subtle facial movements that would be difficult or impossible to achieve using other methods. Furthermore, the study sheds light on how Bangladeshi people perceive facial expressions, as well as the potential applications of BlendShapes in creating realistic digital avatars. The findings of this study could be useful in a variety of fields, including computer graphics, virtual reality, and gaming, where realistic facial expressions and emotions are critical for creating engaging experiences. REFERENCES Carrigan, Emma & Zibrek, Katja & Dahyot, Rozenn & McDonnell, Rachel. (2020). Investigating perceptually based models to predict importance of facial blendshapes. 1-6. https://doi.org/10.1145/3424636.3426904 Chen, C. Garrod, O. G. B., Zhan, J., Beskow, J., Schyns, P. G. and Jack, R. E. "Reverse Engineering Psychologically Valid Facial Expressions of Emotion into Social Robots," 2018 13th IEEE International Conference on Automatic Face & Gesture Recognition (FG 2018), 2018, pp. 448-452 https://doi.org/10.1109/FG.2018.00072. Farah, M. J., Wilson, K. D., Drain, M., & Tanaka, J. N. 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