Tampere University of Applied Sciences

Facial Rigging Techniques

Creating Expressions for an Animated 3D Character

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ABSTRACT

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Facial rigging is a sought-after skill in the animation industry. A rigger has to combine their artistic and technical knowledge in order to create believable and visually appealing faces and expressions. The purpose of this thesis was to examine the three most common methods used for facial rigging in the animation industry as well as examine the underlying structure of the face to gain a deeper understanding of the mechanics responsible for its movements.

To accompany the theoretical part of the thesis, a 3D facial rig was produced. The project shows off all the different techniques discussed and goes through the creation process of the character step by step all the way from concept to final product ready for animation.

The theoretical part along with the project provided a solid understanding of the different techniques as well as their advantages and disadvantages. From the project, it could easily be deducted that combing the different methods often leads to the most versatile and flexible end result.

Key words: rigging, 3d, modeling, expressions, animation

CONTENTS

GLOSSARY

3D	Three dimensional
Mesh	A 3D shape formed by multiple polygons
On model	A term used in the animation industry which refers to a character preserving a consistent look across different scenes.
Polygon	A shape formed by connecting vertices
Rig/Armature	A system used to control the movement of a mesh
Subdivision surface	An operation in 3D modeling where each polygon is divided into four
Vertex	A point in 3D space where the corners of polygons meet

1 INTRODUCTION

The human face is the main tool for our communication with each other. Talking, expressions and emotions are all conveyed through our faces, so people tend to look at them a lot. Recreating this complex communication mechanism for 3D animation can be quite tricky and time-consuming. Facial rigging is an important part of storytelling in animation. If it is not done in a believable way, it can cause a disconnection between the viewer and the character.

Facial rigging is the process of creating a control system for a 3D character which allows an animator to puppeteer the face. There are several ways of doing this, but this thesis will concentrate on the three most common ones: bone based facial rigging, blend shape based facial rigging and mixed facial rigging systems.

Going through these different methods and their advantages and disadvantages provides a solid understanding of which kind of rig to use and when to use them. At the end of the thesis, all the techniques and methods will be put to use in practice by creating a fully functional face rig for a stylized 3D character all the way from concept to a finished product ready for animation.

This thesis goes over the basic steps and principles of facial rigging in order to give a basic understanding of the process even to those with no prior experience in facial rigging. The thesis does not go into program-specific details but instead covers the universal topics and methods of working that would apply to any rig being built.

2 ANATOMY AND EXPRESSIONS

2.1 Anatomy of the face

Before getting into the technical side of creating the character, it is good to understand the basics of how the human face works. Understanding the underlying mechanisms of the face will inform a lot of decisions down the line on how the face should move and deform.

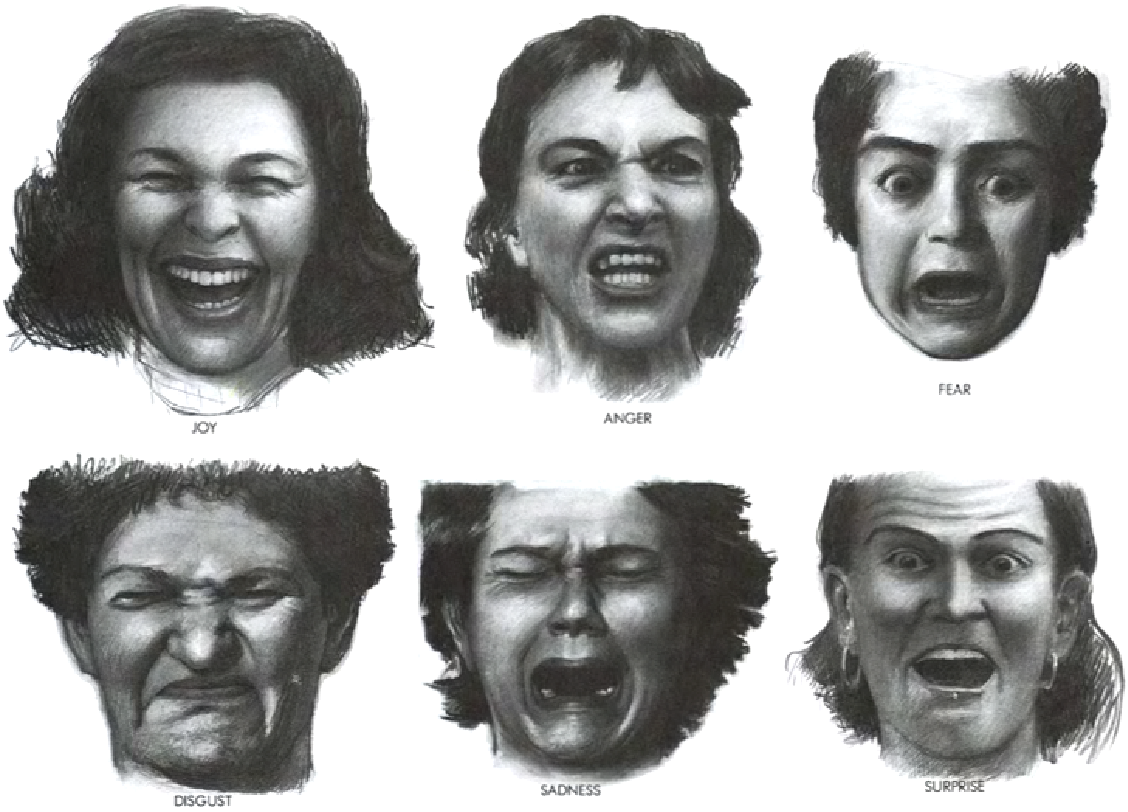
When thinking about the anatomy of the face when making expressions for a character the face can be divided into three parts: the skull, the musculature, and the skin and fat on top of them (Picture 1). The muscles are responsible for all the movements of the face. Unlike most muscles of the body that connect from bone to bone and cause large hinge-like movements, most muscles of the face connect instead from bone to skin. This in turn causes more linear movements in which the skin and fat of the face slide across the skull when the facial muscles pull on them. This contraction causes the skin and fat to bunch up creating a lot of folds and wrinkles on the surface of the face. An exception to this is the large jaw muscles which do connect from bone to bone. This causes the jaw to have a very distinct hinge-like movement not seen in the rest of the face. Understanding these basic functions is integral to making readable expressions. (Winslow 2015)

PICTURE 1. Bones of the skull, muscle groups, and fat compartments of the human face each marked out with a different color. (Zarins 2017)

Examining these basic structures of the bones, musculature, and the positions of the fat formations of the face will be fundamental when thinking about the shape and volumes of the face. They will also inform many decisions down the line when creating the 3D model. This will be talked about in more detail in chapter 3 of this thesis.

2.2 Range of expressions

Based on psychological studies by Paul Ekman, humans have six base emotions to which our faces correspond with six base expressions: joy, surprise, anger, sadness, fear, and disgust (Picture 2). These facial movements are a good starting point when examining what the human face is able to do. These expressions map out all the extremes that the face is able to pull into any given direction and all the other expressions are either a slight variation or a combination of these movements. (Faigin 1990)



PICTURE 2. The six basic human emotions: joy, anger, fear, disgust, sadness, and surprise. (Faigin 1990)

Examining these six expressions gives a good sense of what the human face and by extension a good facial rig is supposed to be able to do. The large areas of movement to take into consideration are the brows, eyes, mouth, and the surrounding nasolabial area. These areas show a lot of movement between the different expressions and because of this cause a lot of stretching and folding of the skin. It is good to note that the different parts of the face can move independently of each other so any combination of these movements or even asymmetry within the expressions is possible.

All the wrinkles and folds may not necessarily apply to all characters and even the extent to which they apply varies from character to character. Take for example a baby and an old man. The difference between the amount of folds varies greatly. This can also vary from visual style to style, more realistic style showing more folds and wrinkles whereas a more stylized one might barely have any at all. Still knowing how the face deforms and why these folds and wrinkles are formed is crucial to understanding how to create believable expressions. Not taking the basic functionality of the face into account all the way from the beginning when creating the face can quickly lead to very unnatural-looking expressions. An example of this can be seen in the picture below where simply removing the nasolabial fold leads to the smile seeming quite forced instead of genuine.

PICTURE 3. An unnatural-looking smile and a genuine smile. (Osipa 2007)

2.3 Exaggeration for animation

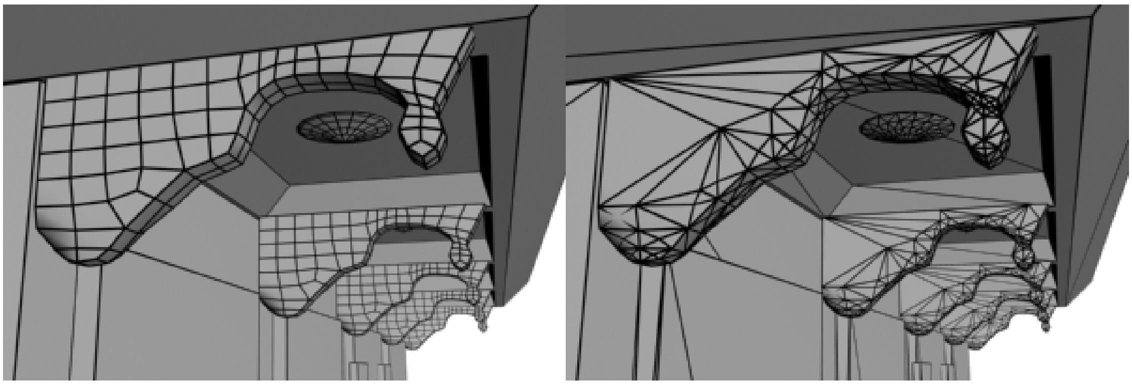
When thinking about rigging specifically in the case of more stylized animation it is good to take into consideration the possibility to deviate from reality and exaggerate things in order to add more life and expression to the characters. When deciding what features a rig should have in order to be adaptable for this sort of more exaggerated animation, a good starting point is to look at Disney's twelve principles of animation: squash and stretch, anticipation, staging, straight-ahead action and pose-to-pose, follow through and overlapping action, slow in and slow out, arcs, secondary action, timing, exaggeration, solid drawing, and appeal (Thomas & Johnson 1995). These are generally accepted as the main principles all animation should follow.

In facial rigging, the principles of squash and stretch, arcs, exaggeration, and appeal are the most important to take into consideration. The rig needs to enable the animator to do all these things in order to be suitable for expressive animation. Some of these will require extra controls like the appeal and squash and stretch whereas others like the arcs and exaggeration might need to be taken into consideration when deciding which type of method to use for a specific task. The different methodologies for achieving these will be talked about later on in the thesis.

3 TOPOLOGY

3.1 Basic topology for animation

Topology in 3D modeling refers to the structure of polygons arranged in a certain fashion to serve a specific function (Munoz 2015). Topology can vary drastically between different purposes and in some cases, two objects may look exactly the same, but the underlying topology can be completely different (Picture 4)(TurboSquid 2017). In animation and rigging the topology should allow for bending and stretching of the mesh in certain directions while maintaining a desired shape and volume. There are several key principles to achieve this.



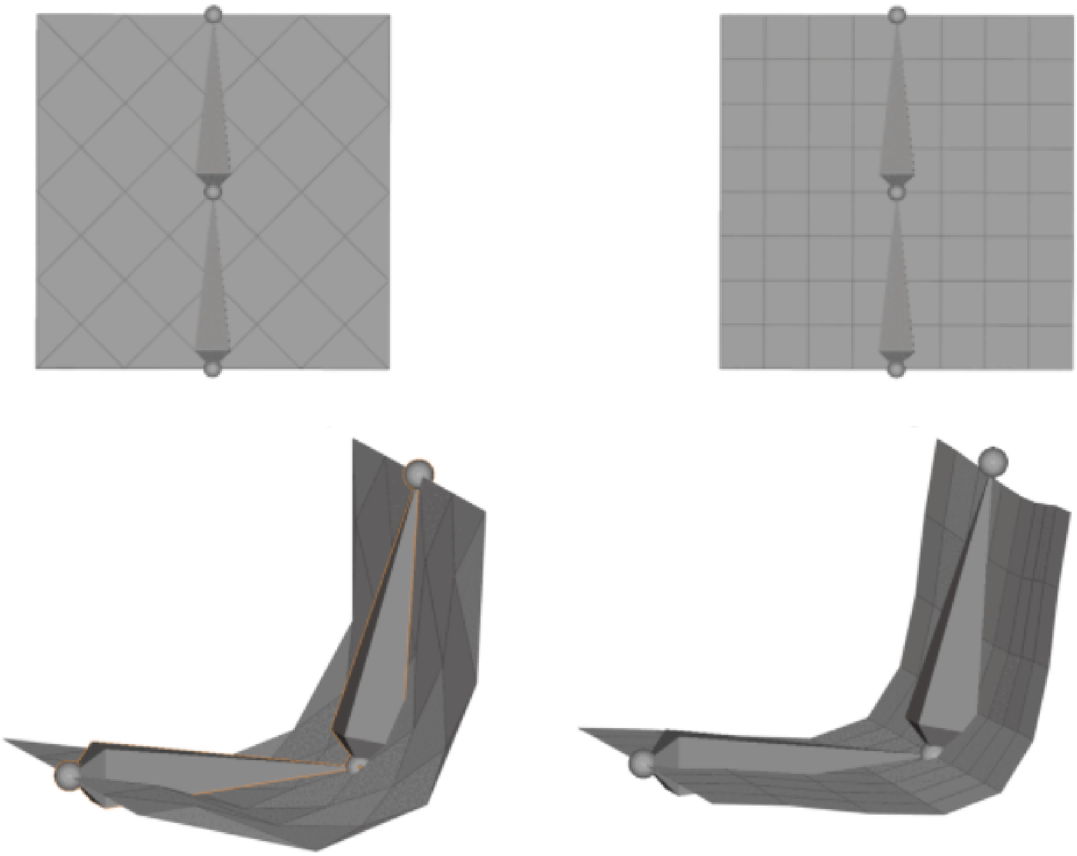
PICTURE 4. Two different topologies that form the same final appearance. (TurboSquid 2017)

The first general principle is to try to maintain a consistent quad structure. Quads are polygons that are formed by four vertices. Quads are generally considered ideal for animation. This is because they are usually easier to work with, produce smoother shading, and generally function better with certain operations like subdivision (Patterson 2022). Another typical polygon is a triangle. Triangles are formed by three vertices and can sometimes be beneficial in the modeling process especially when shapes need to taper to a small point but they should really only be used when necessary. They can cause some shading issues and also often lead to worse results when using certain operations, like subdivision surface, since they are designed to work with quad structure in mind. The last kind of polygon that encompasses all the rest of the multisided shapes is called an n-gon. N-gons are formed by five or more polygons and are typically frowned upon in the world of 3D animation topologies. They have many of the same problems as triangles and often cause even more unpredictable behaviors, especially in shading. (Paterson)

PICTURE 5. Triangle, quad, and n-gon.

In addition to keeping to a quad structure, the mesh should also consist of generally similarly sized polygons. This means that there should not be any drastic size difference between two adjacent polygons. This will ensure that all deformations have the same quality to them, and nothing looks too blocky or out of place. There are of course some exceptions to this especially in facial rigging. For example, the areas around the eyes and mouth where the skin needs to stretch a lot as discussed before. In these areas, it is necessary to add denser topology in order to accommodate for extreme deformations, but everything else should stay quite consistent.

The third and final general principle which is especially important in rigging is to try to align the mesh to the direction of deformation. This means that the loops of the mesh should generally follow the creases and bends that form during movement (Picture 6)(Johnson 2021). This will ensure smoother deformations and generally an easier time during weight painting. Weight painting will be discussed more in detail in chapter 4 of this thesis.



PICTURE 6. Topology aligned to the direction of deformation and against it (Johnson 2021)

3.2 Topology of the face

When building topology for a face, aligning the topology to the direction of movement is especially important. It will ensure that all the creases and folds discussed before will appear in their correct positions and that the face looks natural in any expression, not just the base resting face. To achieve this, we can refer to real-life anatomy.

In the picture below we can see the main loops formed by the muscles on the face. These can most notably be seen around the eyes and the mouth. All the other muscles radiate out from those.

PICTURE 7. The musculature of the face compared to a professional loop structure of an animated character's face. (Zarins 2017) (Miranda 2019)

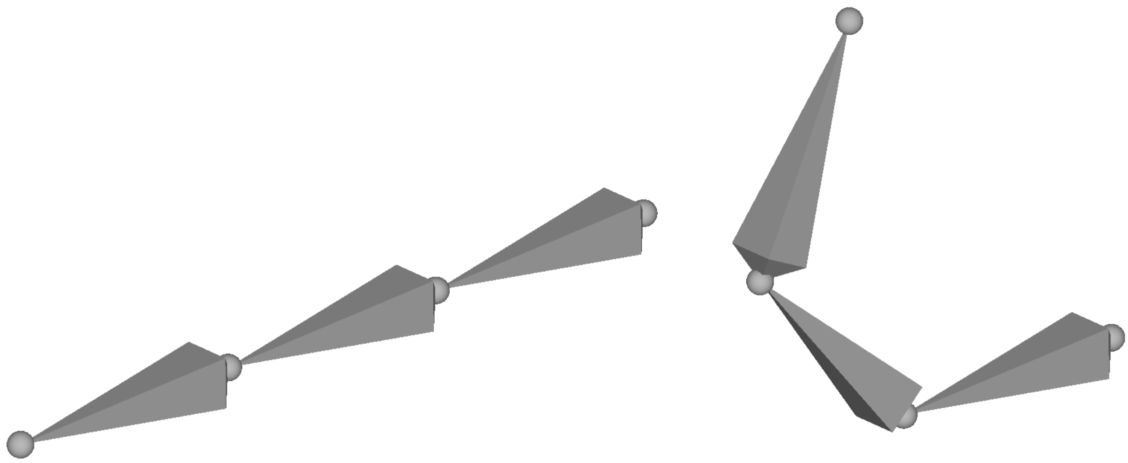
Since the goal of good facial topology is to recreate the movements of an actual human face, even in a simplified form, it makes sense to try to mimic the structure of the underlying musculature as well. This will allow the mesh to deform in a way that closely resembles reality.

There are some discrepancies between the facial mesh and the musculature of the face that can be seen above. These inconsistencies are due to the second important part of the face: the fat and skin. These layers will determine the placement of the rest of the loops on the face, more specifically in the area surrounding the mouth, also known as the nasolabial area. By following these two models and the three general principles of building a good mesh for deformation, it is possible to construct a mesh that will be able to stretch and deform in a very similar manner to a real human face.

4 BONES

4.1 What are bones

In rigging, bones are the basic unit of an armature and form the basis of almost all rigs. Bones are a simple visualization of points in 3D space that control the deformation of a mesh and allow an animator to move a model. They are generally organized in a hierarchy where they are connected to each other via parent-child relationships. This allows moving one bone to affect other bones as well, resulting in a chain-like movement. (Blender 2021)



PICTURE 8. Bones connected to each other via parent-child relationship move in a chain-like fashion.

Bones can be classified into two different categories: deformation bones and control bones (Blender 2021). Deformation bones have a set of vertices assigned to them that follow the transformations of the bone. These vertices are set to follow a certain bone in a process called skinning. This process will be further explained in the next chapter.

Control bones are bones that do not have any vertices directly assigned to them but instead control other bones or blend shapes (Blender 2021). They can have other bones parented or constrained to them thus allowing an animator to for example move multiple bones at once. They can also act as sort of a switch to drive a value of for example a blend shape often allowing for more intuitive control over more abstract values inside a 3D program (Blender 2021). Constraints and drivers will be discussed more in-depth in chapter 7 of this thesis.

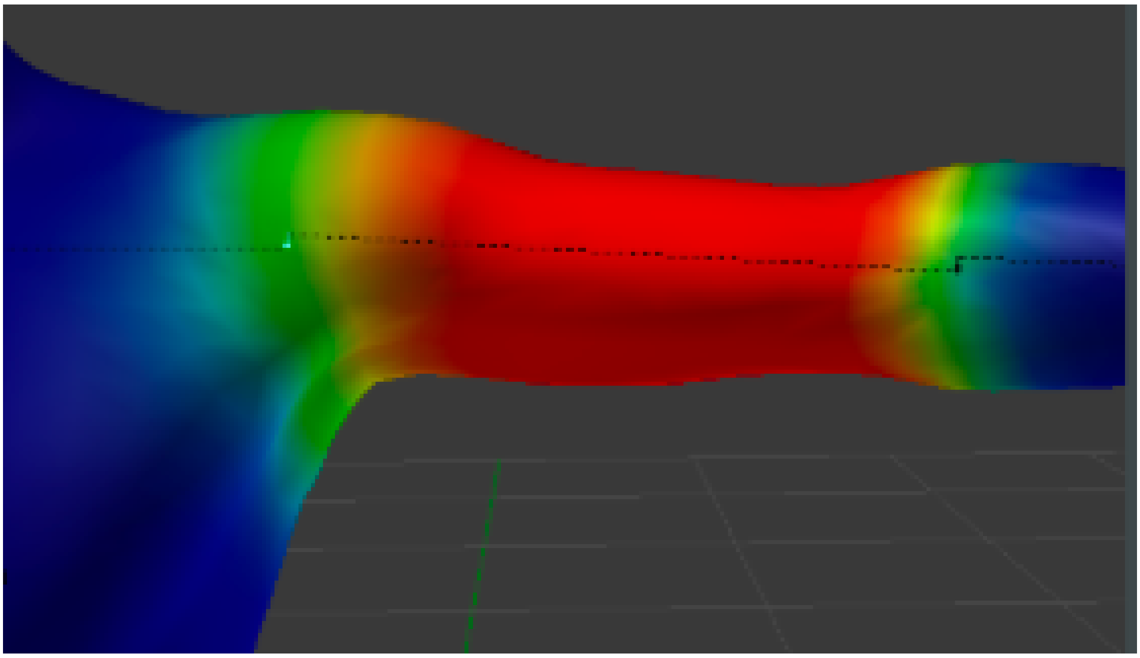
4.2 Skinning

Skinning is the process of binding a mesh to deformation bones. When a mesh is bound to bones, it will follow transformation of the bones. This way the mesh forms a sort of “skin” around the armature (Autodesk 2018). The goal of this process is to make the mesh follow the movement of the bones in an as smooth and natural way as possible.

The binding process is done by assigning a weight from zero to one to each vertex which corresponds to specific bones in the armature. Vertices can be weighted to multiple bones at the same time. The weight value specifies how much the vertices will follow the transformation of the bones. This process is usually sped up by some sort of automatic calculations that most 3D programs have built-in which sets the weights based on each vertex's proximity to a bone. The automated skinning rarely produces a perfect result but usually offers a great starting point for setting the weights. (Blender 2021)

The weights of each bone are stored within the mesh in collections called vertex groups. These groups are often visualized with a heat map representing all the values assigned to a specific deform bone (Picture 9). In the heat map, warm colors represent the weight of one, and cool colors represent the weight of zero.

The weights of each vertex can be set individually, but this can get very tedious, especially with very dense meshes. Because of this most 3D programs include tools to speed up the process by allowing the rigger to manipulate larger amounts of vertices at once. This process is called weight painting. Weight painting allows a rigger to paint the heat map straight onto the mesh, thus allowing for easier manipulation of vertex groups.

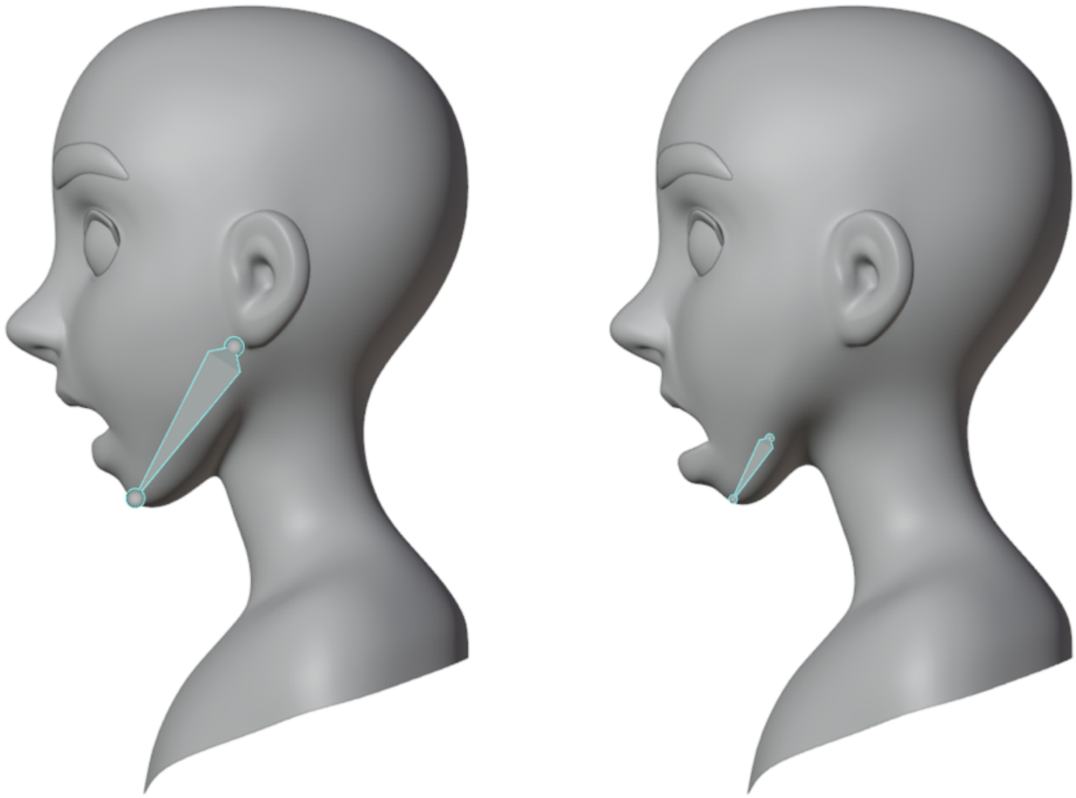


PICTURE 9. Visual representation of the vertex weights assigned to an upper arm bone. (Gavilan 2020)

4.3 Bone placement

Sometimes no matter how good the skinning is or how well the topology is built the deformation just does not look right. This might be due to an often very overlooked aspect of rigging which is bone placement. A general rule of thumb when placing the bones is to place them in the center of mass of whatever is being rigged (Motomura 2021). This usually results in a clean bend in any direction the mesh is deformed in and usually works best for automatic skinning calculations (Blender 2020).

In addition to this, it is very important to once again observe the real anatomy and see where the real joints in the human body connect (Motomura 2021). Finding out exactly where for example the human skull connects to the spine or where the jawbone connects to the skull will greatly impact the resulting deformation (Picture 10). Some of the errors created by bad bone placement can be fixed with methods that will be talked about later on in this thesis but doing it right from the beginning will save a lot of time and headaches later down the line.



PICTURE 10. Good vs bad jawbone placement with the exact same weight painting and topology.

4.4 Advantages and disadvantages

Bones are great for allowing a wide range of movement and can offer a very high level of control for the animator (Wagner 2020). They allow for precise control with easing and curves when animating. In general, bones produce very natural-looking movement because they act very similarly to our own bones, having specific points of movement affecting a certain part of the skin around it. Therefore, they are a great tool to use especially in areas of large rotational movement, like the jaw and eyes.

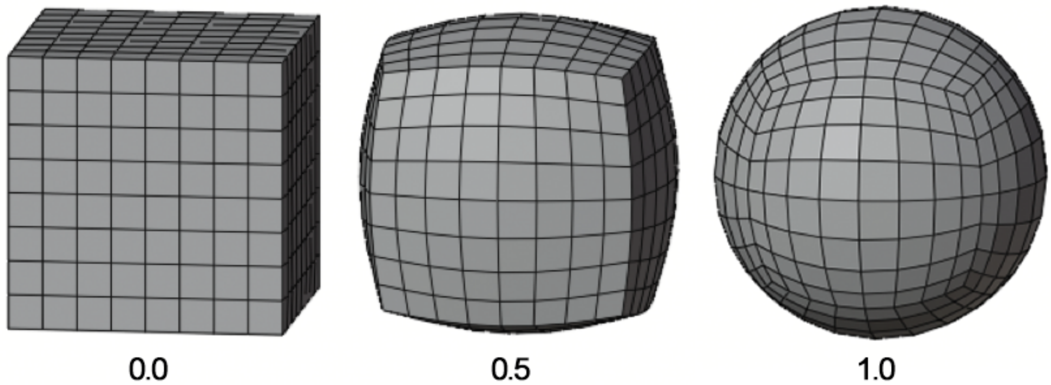
But using bones is not necessarily always the best option. Setting up the bones in their correct positions and assigning all the different weights can be very time-consuming and requires a lot of knowledge from the rigger to do well. A few bones can be easy enough to set up, but when there starts to be tens or hundreds of bones it can get quite difficult to manage all of them.

Another drawback to using bones is the lack of fine control (Wagner 2020). Usually, bones are assigned to large areas of skin. Adding more bones means more weight painting which takes more time and can cause more errors along the way. Because of this, achieving things like small wrinkles by using bones is quite difficult and often requires the use of another technique called blend shapes.

5 BLEND SHAPES

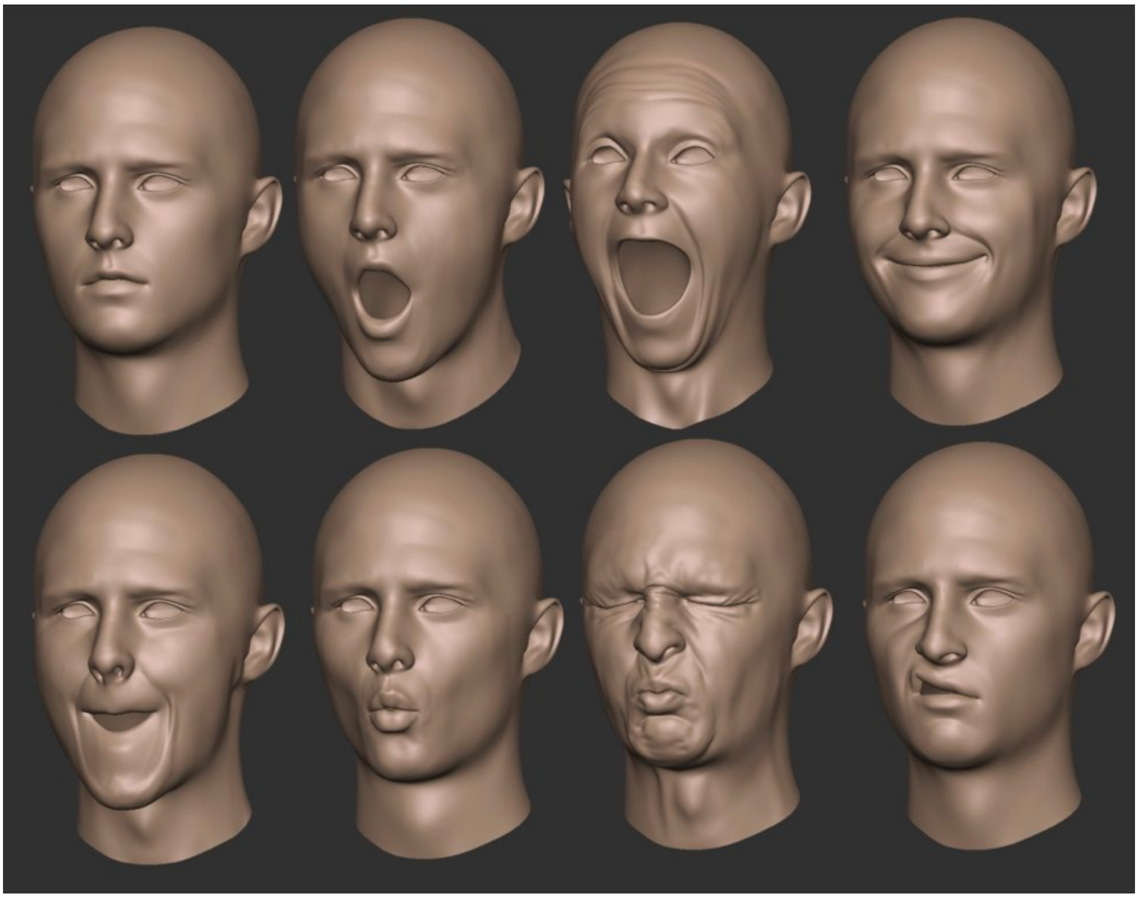
5.1 What are blend shapes

Blend shapes, morph targets, or shape keys seem to be called a different thing in every 3D program you come across. No matter the name, they all function the same: they take an existing mesh and morph it into another shape. This can range anywhere from moving a single vertex to a bit better position to morphing the whole shape into a completely different one. (Blender 2021)



PICTURE 11. Morphing a cube into a sphere using a blend shape. The value of the blend shape is shown below the shape.

Blend shapes make it possible to deform the mesh in any way, the only restriction being that you cannot add or remove vertices. Each of the vertices can be moved individually, which allows the artist to create very large movements like opening the mouth or very fine details like adding small wrinkles on the face. This level of control is why many of the modern facial rigs choose to use blend shapes for most of the animations instead of bone-based systems.



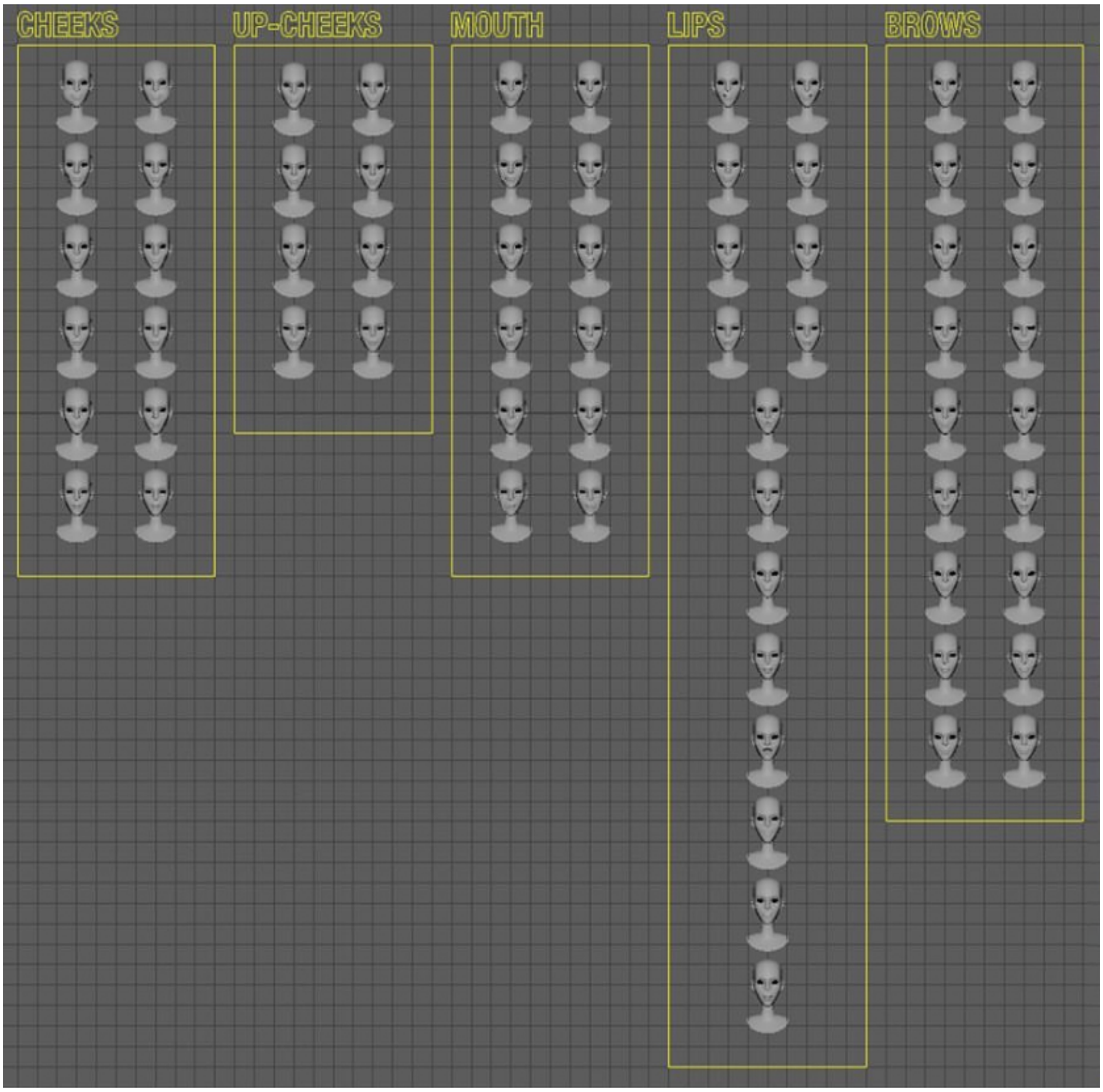
PICTURE 12. Blend shape-based expressions. (Hefley 2014)

After the blend shape has been created it is possible to blend between the original mesh and the blend shape mesh using a simple slider. The vertices are linearly interpolated from point A to point B. This allows for in-between states to also be used, like for example only opening the mouth halfway instead of opening it fully, like the blend shape was built to do.

5.2 Combining blend shapes

Using blend shapes for facial animation is a great way to create very specific expressions and they allow the rigger to create a rig that will always stay on model no matter what the animator might do with it (Wagner 2020). However, creating a blend shape for each expression, like in the picture 12 can get very tedious. Thinking of how many different faces a character might make during a movie for example, when talking and emoting, the number quickly becomes hundreds, even thousands of individual faces that would need to be created.

Luckily blend shapes can be combined. It is possible to use multiple different blend shapes at once on a single mesh. When using multiple blend shapes at once, the movement of the vertices is calculated additively (Wagner 2020). This way the rigger can create multiple different expressions from just a handful of blend shapes. This is the standard way of creating blend shape based facial rigs. Doing it this way cuts down on the required blend shapes drastically but even so it can still take quite a few to get the full emotional range of a single character as can be seen in the example picture below.

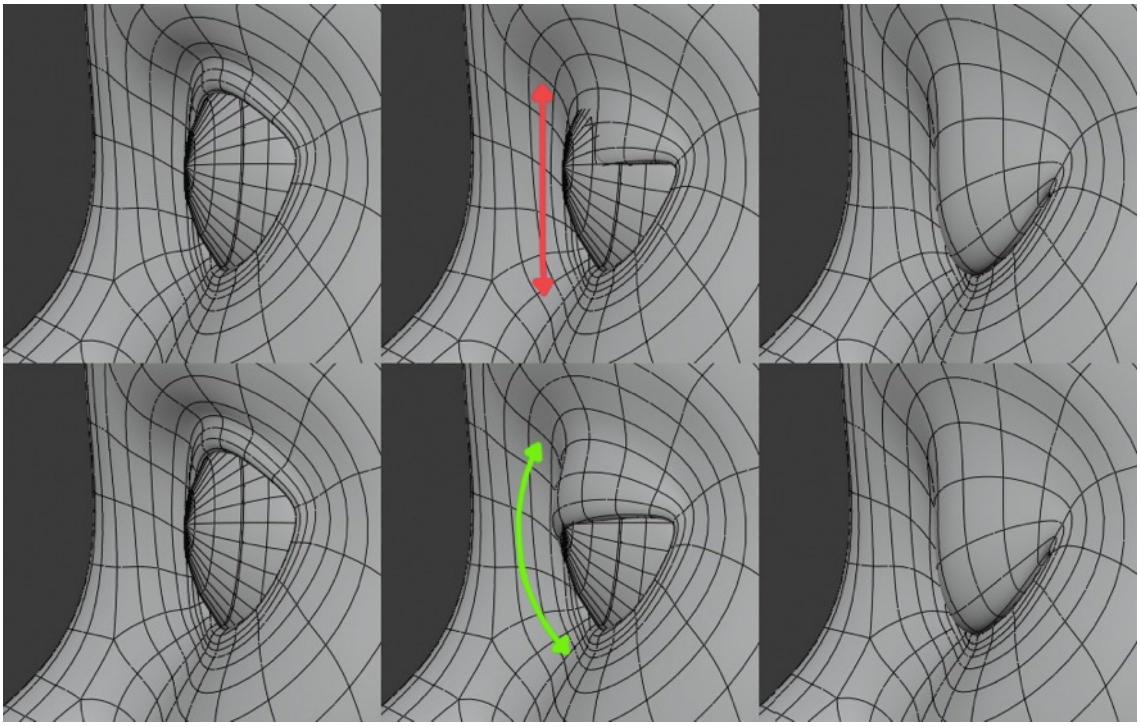


PICTURE 13. Single characters facial blend shapes laid out amounting to a total of sixty-six different variations of the mesh. (Ares 2019)

5.3 Corrective blend shapes

Corrective blend shapes are blend shapes that try to fix errors that might occur during a particular deformation of the mesh (Autodesk 2017). These might be due to two different blend shapes overlapping in an unwanted way or they can also be used to fix unwanted deformations bones might cause. These sorts of blend shapes can be very useful no matter what kind of rig is being built. They can even be used to compensate for bad bone placement, which was discussed before, but in general, they should be kept to a minimum and instead the cause of the errors should be fixed.

A sort of variation of this is a technique called in-between blend shapes. Instead of fixing problems with the deformation, in-between blend shapes fix errors in the movement. Because blend shapes always move linearly, they can cause problems in certain situations where a more curved movement path might be more desired. This can be achieved by creating a blend shape that triggers when another blend shape is for example at its halfway point. This way it is possible to alter the blend shape's linear movement path to a more triangular one for example. More blend shapes can be added in order to achieve smoother curves. (USD 2018)

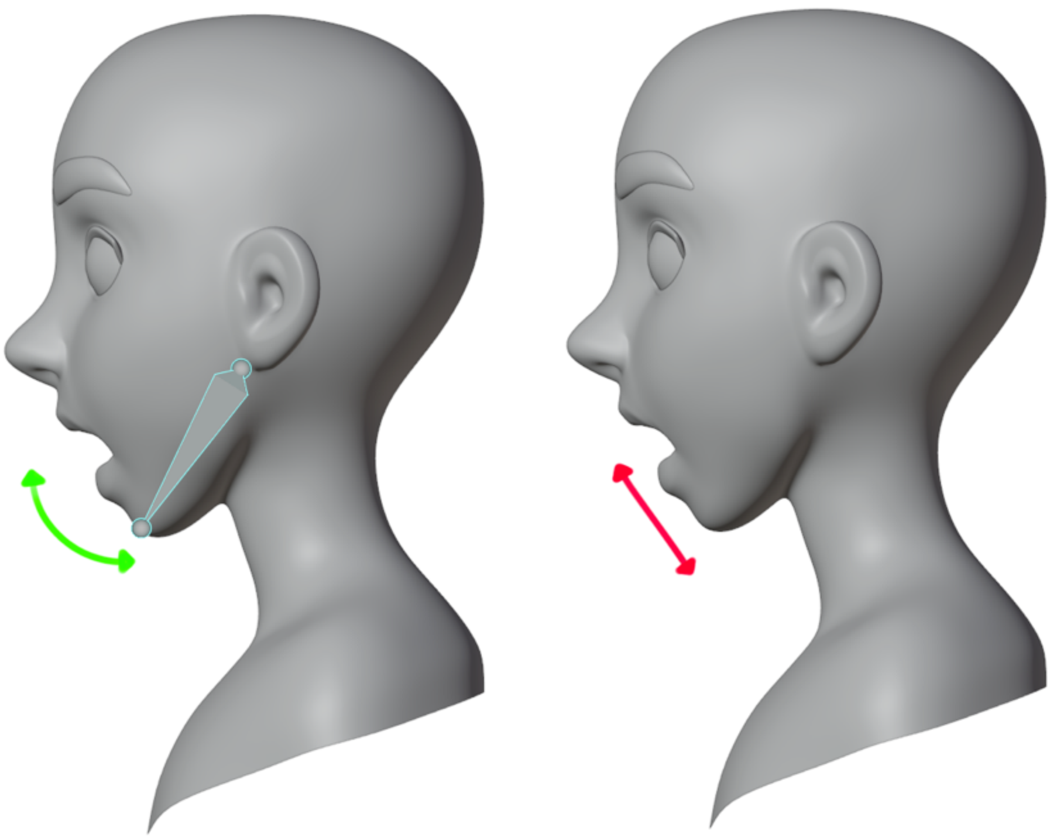


PICTURE 14. Eyeblink blend shape without and with an in-between blend shape.

5.4 Advantages and disadvantages

Using blend shapes is generally a safe option. They are fast and straightforward to set up and allow the artist to create very specific shapes and details for animation. They can also be a great tool for keeping the character on model and limiting how much different areas of the face are able to move. This way, multiple animators can all recreate the same exact smile or frown without fail. Generally, blend shapes are also a more performance optimal solution, because they rely on a very simple linear calculation. This ensures the rig stays lightweight and runs on even lower-end devices. (Wagner 2020)

The biggest downside to using blend shapes is also their simplistic linear movement. This is because of the basic function blend shapes are built upon: all the vertices move from point A to point B linearly. Since most big movements in the human body are based on arcs, it is quite hard to recreate them with blend shapes without using in-between blend shapes. Creating those for all possible arcs can get quite tedious.



PICTURE 15. Jaw movement with a bone vs with a blend shape

6 MIXED RIG

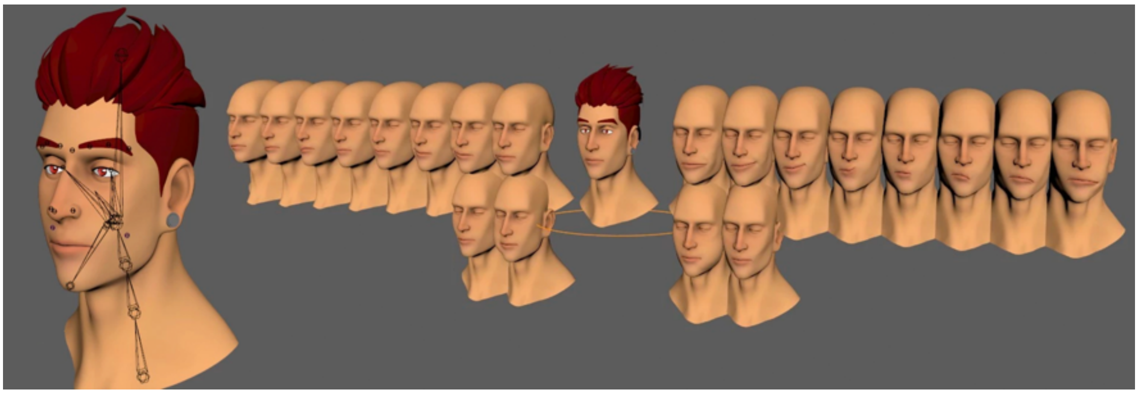
Both bone based rigging and blend shape based rigging methods have their own advantages and disadvantages. A comparison between the two can be seen in table 1. Both methods are quite commonly used in the animation industry and can work well on their own.

TABLE 1. Bone and blend shape pros and cons.

	Advantages	**Disadvantages**
Bone	Unlimited movement	Hard to get fine details, Takes long to do well
Blend Shape	Easy to control shapes, Fast to set up	Hard to achieve arced movements

However combining blend shapes and bones can offer the best of both worlds: the flexibility of bones and the fine control of blend shapes while also avoiding the downsides of each. Bones can be used to create big arcing movements that the blend shapes are not able to produce and blend shapes can be used for fine details that the bones are not able to produce. This way the two methods complement each other and form something called a mixed rig.

The general setup for mixed facial rigs is to use bones for the bigger movements like the jaw, eyes, and neck while reserving the smaller movement of facial muscles for blend shapes. It is good to note that this is not the only way to do it and there are plenty of other ways of dividing the two, based on the needs of the rig. For example, a more exaggerated character might need more bones in the rig in order to allow for more of freedom of movement for the animators, whereas in a more realistic face, more blend shapes are preferable because they limit the movements to the natural range of the face, thus providing quite realistic results.



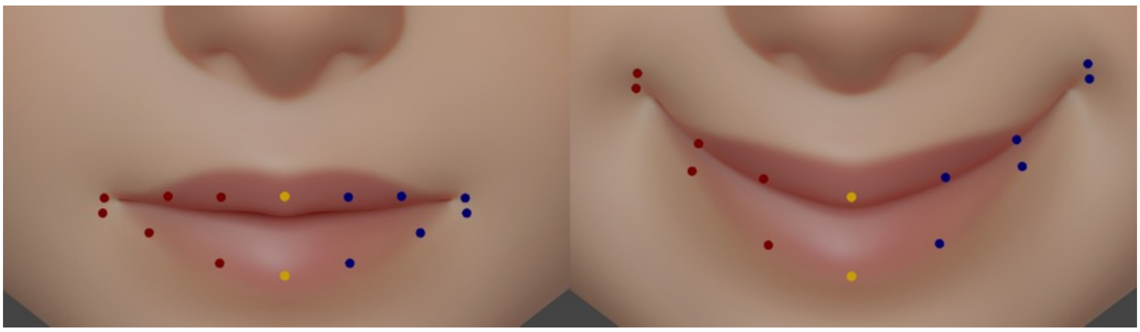
PICTURE 16. Quite typical division between bones and blend shapes in a facial rig. (Wagner 2020)

7 CONTROLS

7.1 Constraints

When adding a lot of bones into a face rig, it can quickly become quite overwhelming to control each of them separately. Parent-child relationships can help to a certain extent but often face rigs need something more sophisticated in order to be easy to use for the animators. This is where constraints come in.

Constraints allow the rigger to set a certain constraint to the position, orientation, or scale of a bone. This way it is possible to add limits on for example how much a character can smile in order to keep the character on model. Perhaps more importantly it is possible to constrain a bone to another bone. This way it is possible to add more complex relationships between the different parts of the skeletal structure. The mouth is a good example for this. If the lips are rigged using bone-based methods, it can be quite tedious to move each individual bone to create a smile for example. By using constraints, it is possible to make all the bones around the mouth follow the corner bone based on their proximity to it. This way the bones closest to the corner bone follow it almost fully and the next one a bit less and so on. This allows the animator to move just a single bone to create a convincing smile instead moving of each bone individually as can be seen in the example picture below. (Autodesk 2020)

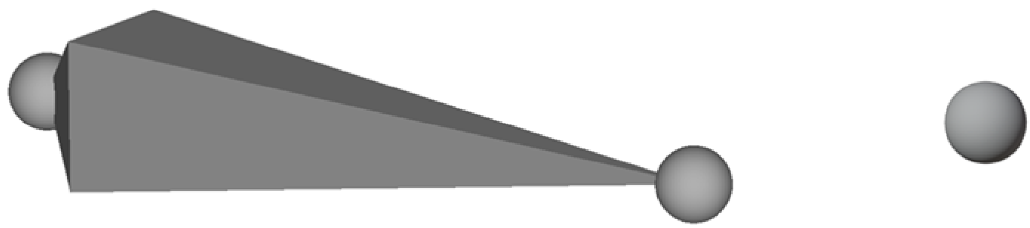


PICTURE 17. Mouth bones moved from default position to a smile.

7.2 Control shapes

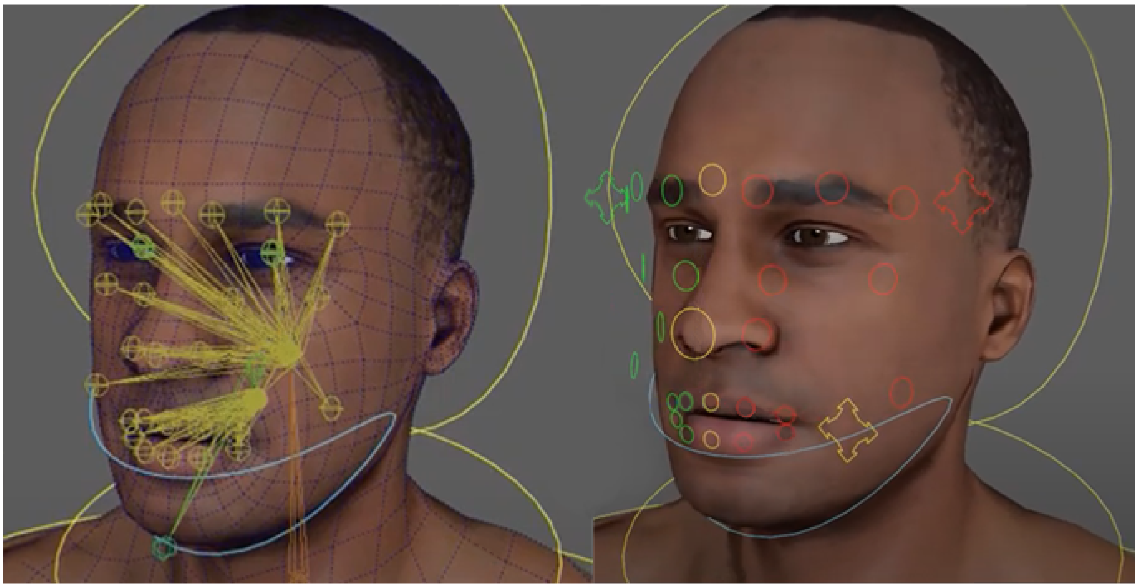
No matter what kind of a rig is being built, it is always important to make it easy to control. By default, bones are placed inside the mesh, so selecting and moving them can be quite difficult. It is possible to display them on top of the mesh, but especially with facial rigging, this makes it often quite hard to see what is actually happening with the face of the character as can be seen in picture 19.

This is where control shapes come in. Control shapes are simplified objects that can be used to represent a bone. This allows the rigger to create much more simplified controls that are easy to grab on to and manipulate. The basic octahedral form that most 3D programs use to display bones is great for displaying all the information bones can have, like the direction, rotation, and roll, but often the animator does not need all that information. Especially on the face most of the time a bone can be simplified to just a simple circle or a sphere that is easy to grab on to and does not obstruct the face.



PICTURE 18. Default bone shape vs a simplified control shape.

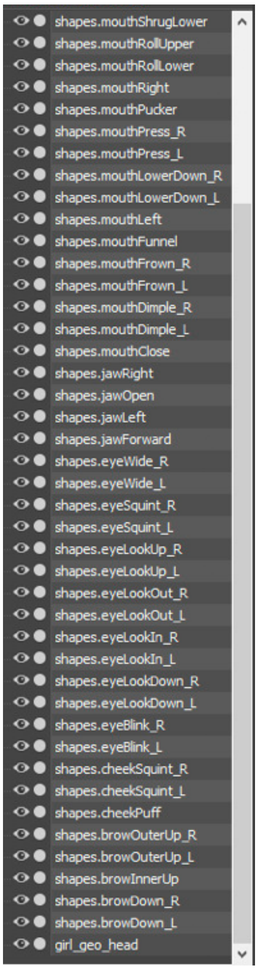
Generally, the goal of using control shapes is to allow the character to be seen as well as possible and to allow more intuitive controls for the animator. This usually involves converting most of the control bones into spheres and circles but they can also be customized further to fit the character's face or the purpose of the control such as creating arrows to convey the directionality of the control. An example of these can be seen in picture 19.



PICTURE 19. Face rig before and after control shapes. (Ward 2019)

7.3 Drivers

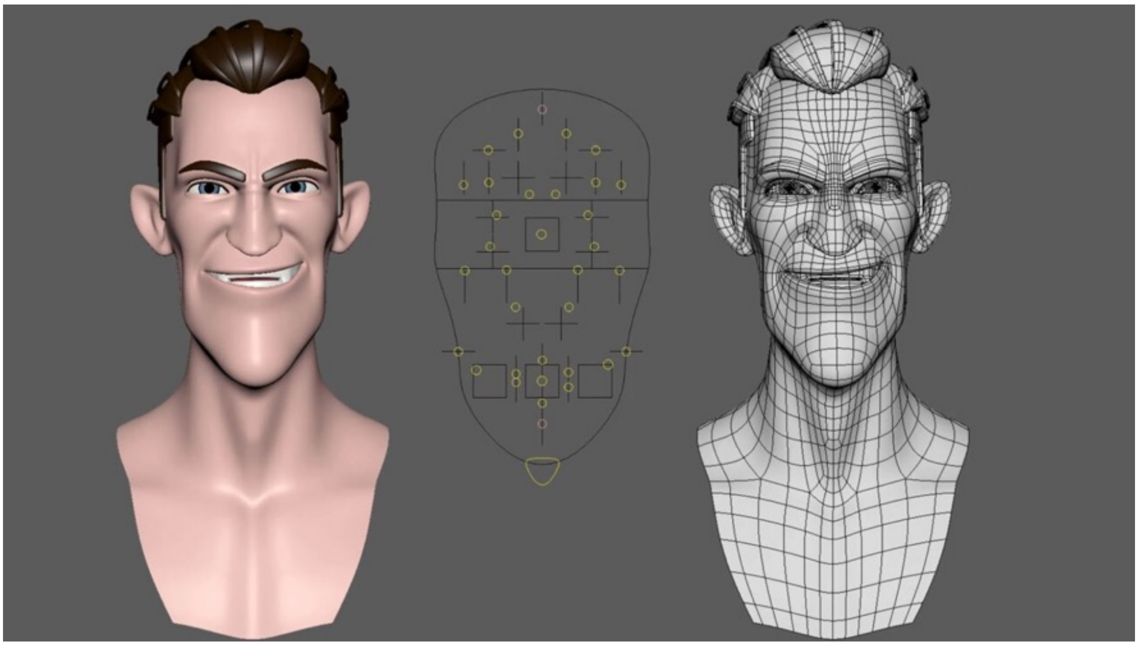
Blend shapes can present a similar issue to the bones where they can get quite confusing to use because of the default way they are visualized inside most 3D programs. Blend shapes are generally viewed as a list of names, which have sliders attached to them that allow the user to control the intensity of the blend shape (Picture 20). This way of controlling them becomes quite unintuitive once there starts to be tens of blend shapes from which the user has to always find the correct one to tweak some values. In order to make all of that a lot simpler and intuitive for the animators, most rigs generally use drivers.



PICTURE 20. List of blend shapes of a blend shape based face rig. (Tariq 2020)

Drivers are a way to control a value inside a 3D program by using a simple mathematical expression (Blender 2021). A value inside a 3D program, like for example a position of an object, can be mapped onto another value, like a blend shape. By controlling the position of the object, the value of the blend shape is affected. This way it is possible to create much more sophisticated and easier to understand control systems for blend shape based facial rigs.

A common way to do this is to create a simplified 2D representation of the face and place it next to the 3D model (Picture 21). Within this simplified version of the face, simple control points can be added which control the intensity of blend shapes by using drivers. This way it is a lot simpler for the animator to just move a control point on the simplified face control system and see the corresponding point moving on the 3D model. By setting the controls off to the side it is also easier to see the face without the controls being in the way.



PICTURE 21. Simplified 2D control system for the blend shapes of the face. (Torres 2021)

Drivers can also be used in combination with bones and control blend shapes within a mixed facial rig. In this kind of solution, bones can be used to control the value of blend shapes. These bones can be placed onto the spot on the face that the blend shape controls and set up so that the movement of the bone controls the value of the blend shape. This way it feels no different to use than the bones used for deforming the face.

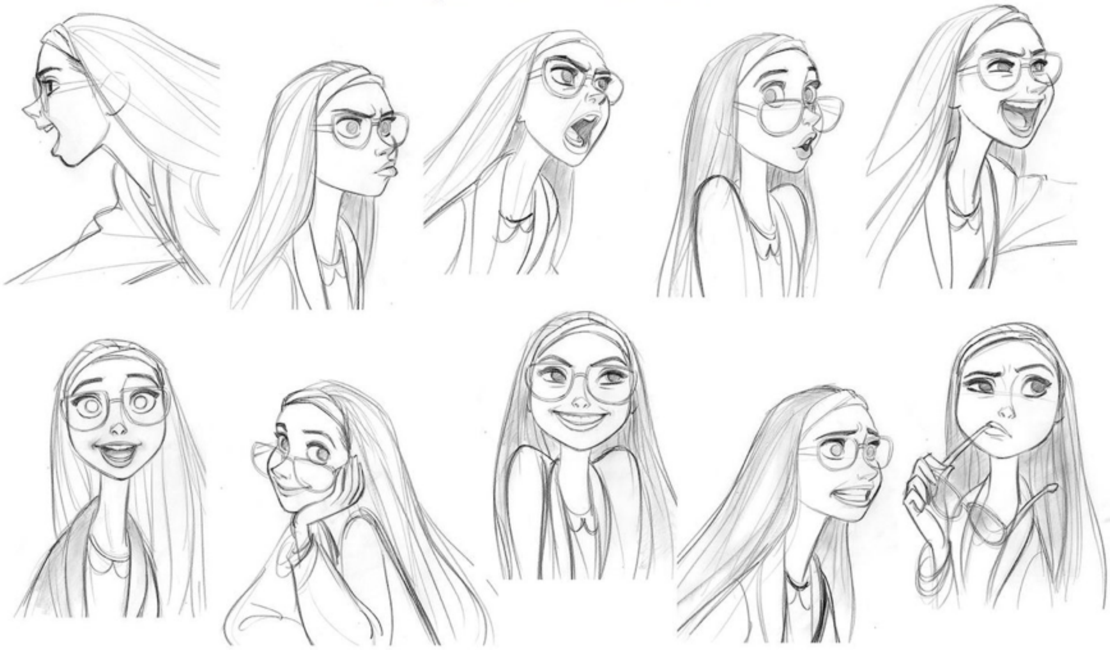
8 PROJECT

8.1 Planning

To support the theoretical part of this thesis a production ready 3D face model and rig were created in order to test and prove the concepts discussed above. The goal of the project was to create an as expressive and appealing character as possible. For this, a lot of reference from big animation movies made by companies like Disney and Pixar was gathered. The general look of the character took a lot of inspiration from the works of Sergi Caballer and Chad Stubblefield, who are both behind many Disney's most memorable 3D characters.

PICTURE 22. Character models made by Sergi Caballer (picture on the left) and Chad Stubblefield (two pictures on the right). (Caballer 2018) (Stubblefield 2019)

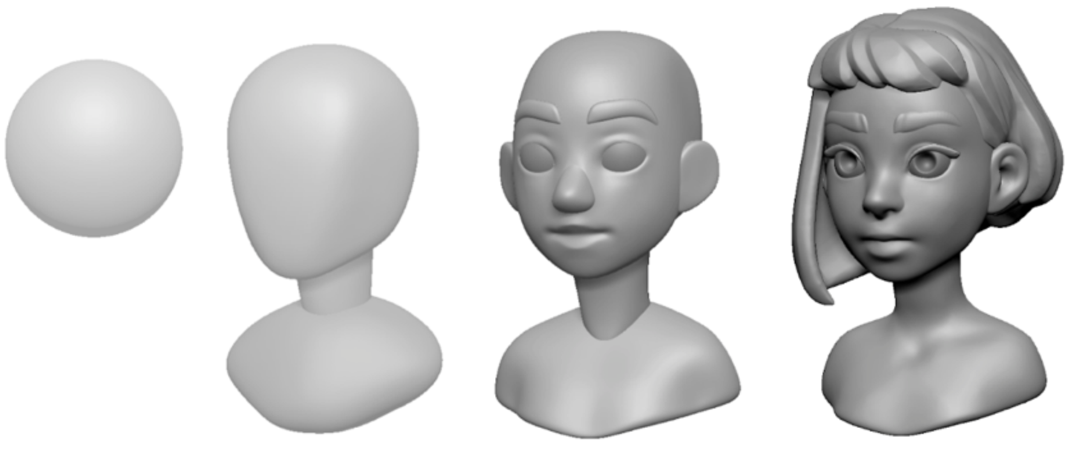
Since the goal was to create as much expressiveness as possible it was also important to gather good references for a large range of facial expressions that could, later on, be used to test the rig and see if all the expressions could be reproduced. For this again Disney's early concept work proved to be a great source. For a lot of the movies, the concept artists create massive expression sheets that show the whole emotional scale of a character. Since the character sheets are generally 2D sketches they often provide really appealing shapes in the faces which can be very useful for more stylized works. In addition, a couple of rig test videos were found. These provided a good reference of what a real professional face rig is able to do and a good goal to aim for.



PICTURE 23. Expressions references. (Kim 2015)

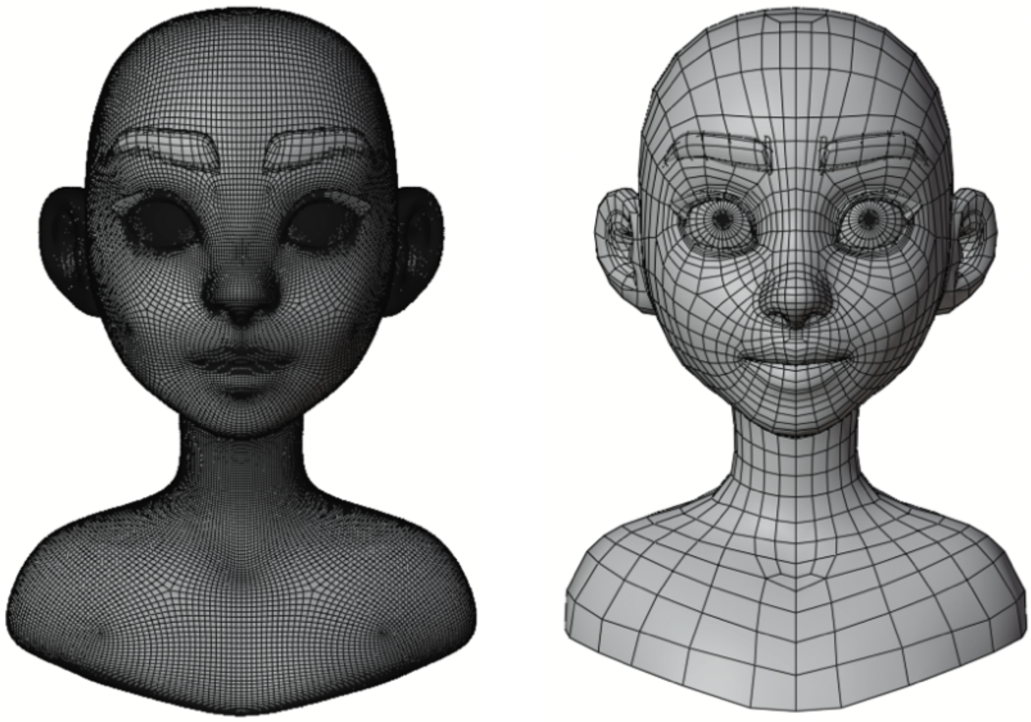
8.2 Modeling

Based on the reference gathered, the actual production of the character could be started. The initial ideation for the look of the character was done in ZBrush, where it was easy to block out all the shapes and proportions without yet having to concentrate on the more technical side of modeling like topology and poly-counts. Generally, this allows for a more creative process to sculpt out the character and provides a nice base to build the topology on top of.



PICTURE 24. The sculpting process.

Using the sculpt it was possible to use the defined shapes to create the final model in Blender using a method called retopology. Retopology is the process of building a simplified topology on top of a usually sculpted high poly mesh in order to make it easier to work with (Blender 2022). In this case, the loops of the face were followed in order to build a mesh that would deform well when rigged. In the process, the number of polygons also dropped from approximately a hundred and fifty thousand down to just over six thousand. This allowed for much easier editing and manipulation of the mesh. In addition models for the teeth, tongue, and hair were all created by using basic polygonal modeling techniques inside Blender.

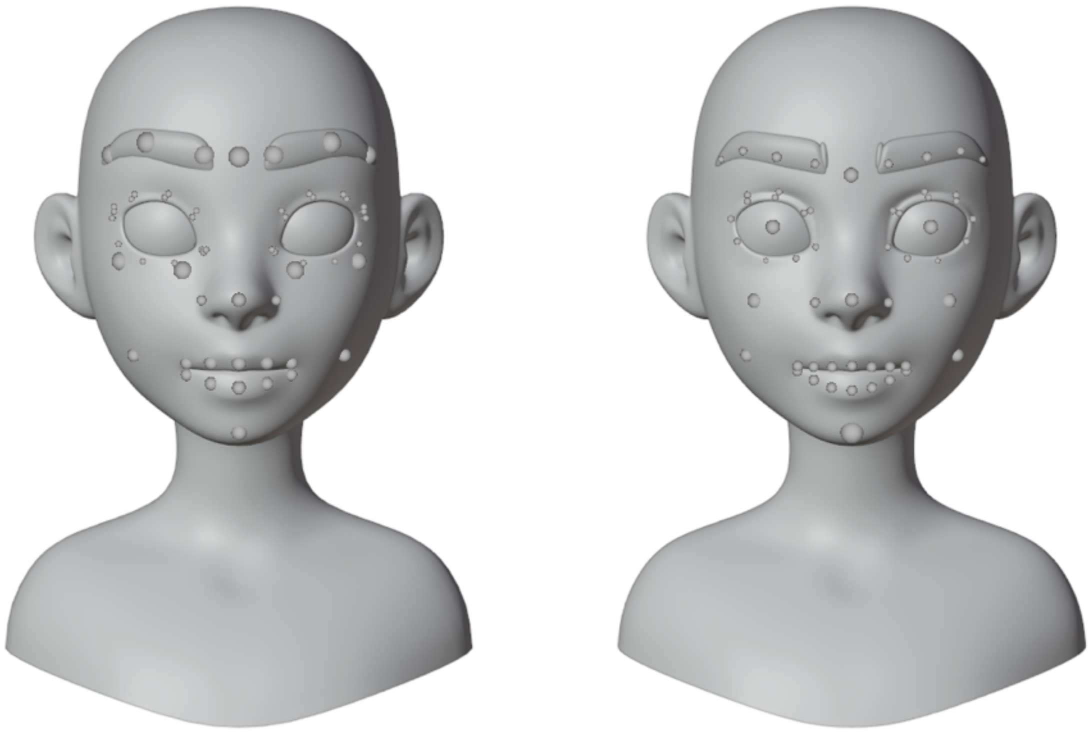


PICTURE 25. Topology before and after retopology.

8.3 Bone rig

After the topology was finished the actual rigging process could begin. At this point, it is good to consider which kind of rig to build for the character. This will depend on the needs of the production the character is made for. Since the goal for this project was to make an as expressive character as possible for animation purposes, a mixed rig was chosen. A mixed rig allowed for the most amount of flexibility when it comes to expressions by creating the big areas of movement using bones and accentuating those expressions using blend shapes.

The first step in building the rig was to block out the rough placement of bones in the main areas of control. This included places like the jaw, lips, eyes, cheeks, and brows. After this, an automated skinning process was performed in order to test out the general deformations and the placement of the bones. This also allowed testing the general feel of the rig by trying out different extreme expressions like smiles and frowns. This clearly highlighted any lack of control or the excess of it. From the first pass, it was evident that the mouth and the brows did not have quite enough control points in order to achieve the desired shapes whereas the eyes had far too many controls to easily manage.

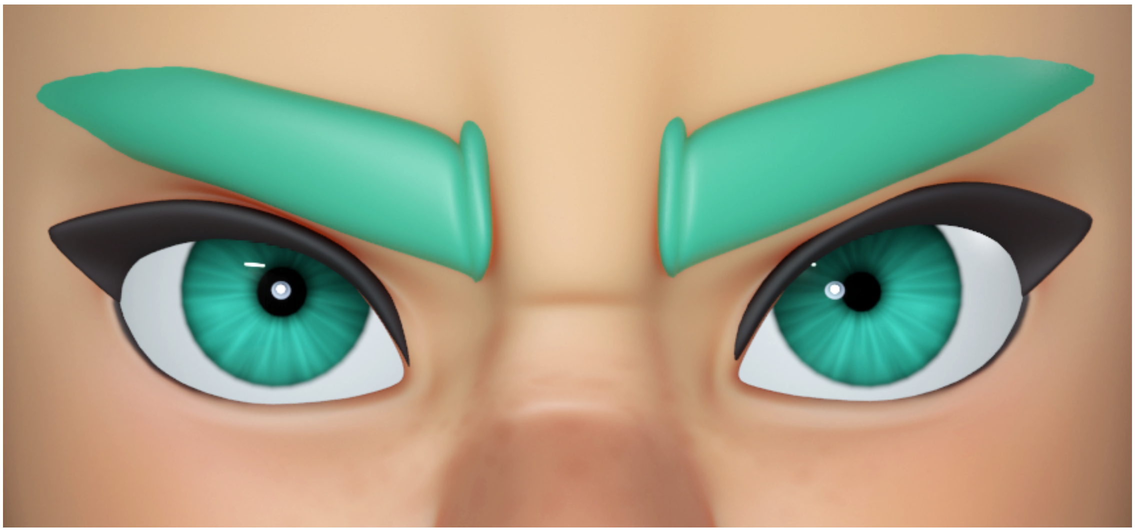


PICTURE 26. The first pass on the position of the bones vs the final positioning. Small changes to the mesh can also be seen, made after testing of the deformations.

After a couple of rounds of adjustments to both the bones and the mesh in order to make the deformations look as natural as possible, some further weight painting was done. Surprisingly little manual work had to be done after the automatic calculations, but of course, there is always some. With this particular model, the eyelids proved to be one of the most challenging parts to get working correctly. Looking back at it they would have probably been better to do with blend shapes, but using bones did give a nice level of control over the shape of the eye in the end.

8.4 Blend shape rig

After the big areas of deformation were taken care of with bones some smaller more fine-tuned deformations could be done using blend shapes that bones were not able to easily produce. Things like wrinkles are notoriously difficult to achieve using only bones so blend shapes were chosen for this task. Blend shape-based deformations were used mainly in the brows to allow for more accentuated angry expressions as well as in the lips to allow for more natural looking curling.



PICTURE 27. Folds in the skin around the brows made with blend shapes.

PICTURE 28. Lips puckering in and out made with blend shapes.

In addition to these bigger deformations, some corrective blend shapes were used to fix some areas, where bone deformation did not produce quite the wanted result. This included areas like the eyelids clipping through the eyeball as well as maintaining an appealing shape on the eyelashes when blinking.

8.5 Controls

At this point, it had become quite evident how unintuitive the rig was to control using the default bones and blend shapes in Blender. To help with this, custom control shapes were created. Most bones could be replaced with simple dots to represent the point of control. For the other bones where the orientation was more important, more custom shapes were created that formed around the face. This allowed for much simpler control over the face and allowed the face of the character to be much more visible during the animation process.

PICTURE 29. Rig before and after control shapes.

In addition to control shapes, drivers were created to control the blend shapes. The drivers were attached to special bones on the face, purely dedicated to controlling them. Some constraints were also added, like the mouth corner technique discussed in chapter 7.1, as well as a constraint for the eyes to look at a specific target and a constraint for the middle of the brows to always be located between the two brows in order to keep the shape of the brow line more fluid in shape. This automated some movements of the face and reduced the need to always hand place bones.

To further exaggerate the expressions the model was already able to produce, some extra steps were taken to better comply with the principles of animation. Separate controls for squash and stretch and some extra controls for places like eyebrows were added. Squash and stretch controls allowed for even more extreme poses and were of great use, especially when creating anticipation and follow-through animations, even if they might look a bit strange in still pictures (Picture 30). The extra controls in the brows for example allowed for more fine control over the shape of the brows. This ensures that appealing shapes are able to be produced no matter what position the brows are in.

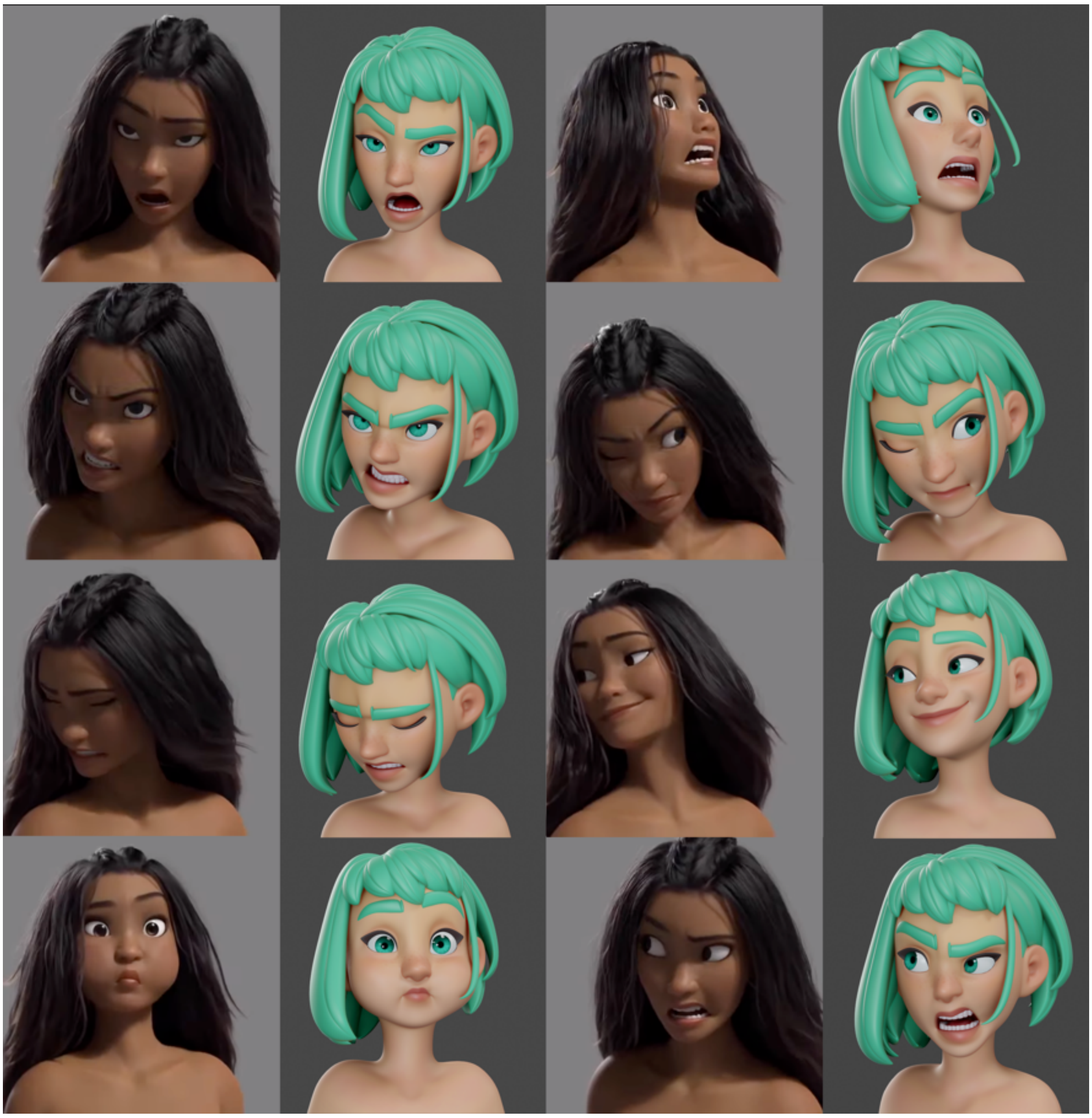
PICTURE 30. An example of squash and stretch on the character.

8.6 Results

The final result of this project is a production ready facial rig ready to be used in Blender. Some expressions created using the rig can be seen below.

PICTURE 31. Results of the project.

In addition, a small animation was created which aimed to replicate the movements and expressions created by Jennifer Hager for a facial animation test using a rig made for Disney's Raya and the Last Dragon movie. This validated the functionality of the rig. Below are some comparison pictures of the Raya rig and the project. A link to the full video can be found in the appendices section of this thesis.



PICTURE 32. Comparison between the expressions of Raya (Hager 2022) and the project character.

9 DISCUSSION

Creating a facial rig is quite the complex process. The three methods discussed in this thesis provide multiple different implementation methods which all offer different advantages and disadvantages. Because of this, it is good to consider using the strengths of different techniques in order to achieve the optimal result.

Technically the bones proved to be optimal for large-scale movements. Wherever flexibility and smooth movement arcs were required bones were the best option. Their downside was the lack of fine control over the small deformations of the mesh, so things like wrinkles were quite hard to achieve. Blend shapes on the other hand proved to be excellent for fine detail work because of the high precision they allow the artist to work with. Their downsides boiled down to the lack of control over the movement arcs they provided. Combining the two whenever possible can offer the best of both worlds and thus allow the most control for the animator.

The techniques discussed proved to be very useful in creating an appealing stylized character with a wide range of expressions. Following the anatomy of the real human face made the movements look very natural and thus kept the need for manual fixes quite minimal. The combination of bones and blend shapes allowed for very fine control over the deformation while also allowing a large range of movement to be utilized.

Possible future development for this research would be to look into FACs (Facial Coding System). FACS mark out each movement of the muscles of the face, which can be followed in order to reproduce a highly accurate recreation of the movements of an actual human face. Another technique not discussed in this thesis would be the use of curves. Curves can be a great tool to allow for flexibility and fine control over the shapes of the character, but can be a bit more complex to execute in practise.

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APPENDICES

Appendix 1. Facial rig test animation

Link to Youtube video: https://youtu.be/moAQ_XWwro0