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MSc. in Computer Animation
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Date of Submission: 11th September '06

Implementing a Facial Animation System using Bones in Maya

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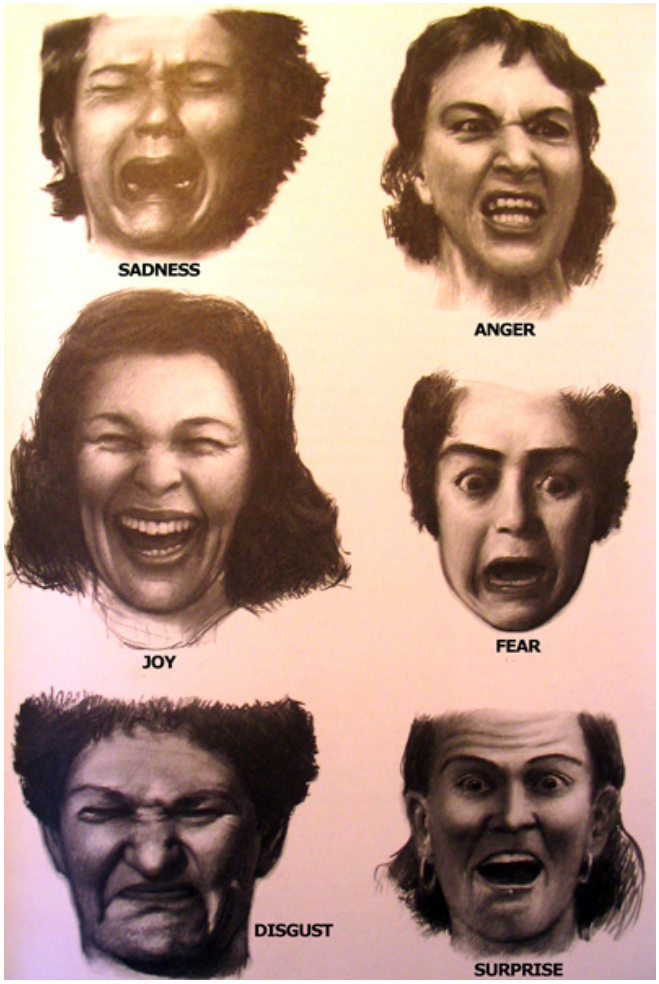
1. Introduction

There are numerous creative solutions that allow the animators to play around with parts of the head in order to achieve a desired feeling. However, such effects and implementations require extensive knowledge of the facial structure, such as muscles, bones, as well as the expressions a human-like face can take. Creating a realistic head structure though, requires a great amount of research. It is important to take into consideration the head's features or else this might lead to poor development, and consequently to poor animation. The purpose of thoroughly analysing the cranial anatomy is to achieve most, if not all, desired facial expressions, which can lead to outstanding facial animations. Additionally, a very good understanding of the muscle structure would also be required (see Appendix A), as muscles are responsible for any movement of the human body.

Furthermore, Faigin (1990) certifies that most researchers have concluded to the fact that there are six universal expressions. Those expressions illustrate emotions, such as Sadness, Anger, Joy, Fear, Disgust, and Surprise. Other faces that could instantly be recognised, but are considered ambiguous are Pain, Sleepiness, Passion and Physical Exertion. Among those expressions there are several others that would be recognisable only by taking into account the situation the character is into. Figure 1.0 illustrates the above six universal expressions.

Figure 1.0 - The Six Universal Expressions



1.1 Aims and Objectives

The purpose of this project will be to investigate different methods for facial animation and rigging, and subsequently try and identify the best possible method for developing a facial expression model, using bones. That would mean following some standard template as to how the bones should be laid out to allow animation to take place. Another important aspect though will be to create a structure that could be applied on any head model using Maya. Unfortunately, Maya does not have a feature that will allow the modeller to apply a basic bone structure for the face on more than one head. Accordingly, the essential concept is to assist the animators and modellers with a feature that will allow them to apply a facial expression structure onto as many models as they like. There are many ways that this could be done and those will be discussed in detail in the method section.

2. Method

There are various techniques that could allow the movement of a character's face. This is usually done by using some kind of User Interface (UI) that will allow the animator to play around with different types of expressions. Before reaching that point though, it is necessary to think about the structure that the interface will work on. There are two choices; one is to use blend shapes and the other one would be using a bone driven system.

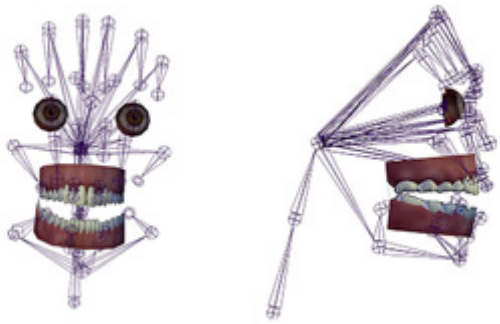
2.1 Skeleton Based

In the Getaway game, the skeleton hierarchy was created based on a study. Two main joints were used as the controls, the neck and the head. The “neck” is the base, the joint that is constrained to the skeleton of the character model. This joint could either be driven by constraints or motion capture data from the character model. This gives a point at which seamless interaction is allowed between the head and body. The “head” joint would control slight head movements: shaking and nodding, random head motions, and positions taken up in different expressions. The head leans forward during anger or downward when sad. This is the joint that all other joints spring from; it was said that it was used as the controlling joint. Wherever it went, the rest of the joints went. Other joints which related to specific muscle groups of the face were:

- Six joints controlled the forehead and eyebrows.
- Three controlled each eye, one in each eyelid and one for the eye itself.
- Two joints, one on either side of the nose.
- Two joints controlled each cheek.
- Two joints on either side of the jaw.
- Three joints in the tongue.
- Four joints controlled the lips.

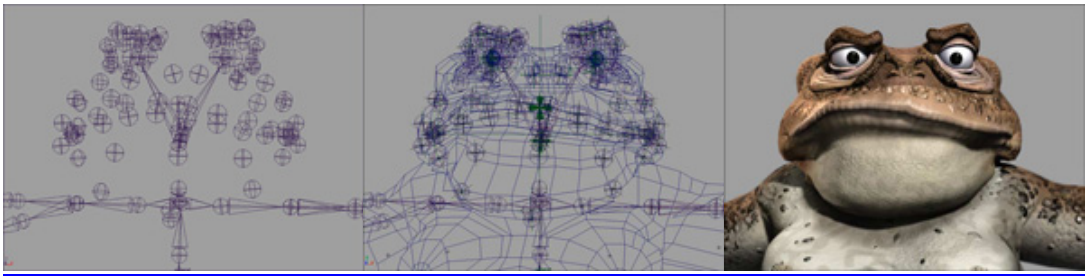
The following figure shows the front and side view of the skeleton hierarchy. (Moore, 2001)

Figure 2.0 - Front and Side View of the Skeleton Hierarchy



Another project was the Cane-Toad project (Silke, 2002), which implemented a more complex bone driven facial animation system. Bones, which are also called joints in Maya, are just groups of vertices that can be weighted with fall off. They avoided using clusters in this project because they thought it was easier to paint weights for bones rather than clusters. This project considered using both blend shapes and bones, as there were a few expressions that could not be represented by using bones alone. Figure 2.1 illustrates the bones structure of Cane Toad.

Figure 2.1 - Cane Toad Bone Structure



This project made use of strong lip synchronisation (lip synch) skills, and consequently they have strong beliefs that using a bone driven facial system might be more efficient in some cases that using blend shapes.

Pros

- Bones can animate using arcs if pivoted by other objects - like the jaw. Because muscles slide the skin over the face they will often move in an arc like manner not linearly like morph shapes. Eg. the skin of the eye lid.
- Bones allow for extra control including the ability to tweak on a shot by shot basis and the ability to offset different part of the face individually and manually.
- Face shapes can be created faster and more easily. The animator only has to worry about a handful of bones rather than a mass of vertices.

- Volume can be maintained more easily because the bones move vertices in weighted groups. Extra attention must be made by a modeller of morph shapes to make sure that face shapes maintain volume and stretch in every shape. It is easy to create a shape that will look fine on its own but bad in animation.

Cons

- Creating a good rig can be tedious and much more complex than a morph target set-up.
- Because bones are groups of vertices they don't allow for specific control on crafting a very specific shapes and wrinkles.
- Bones stored as driven keys will increase file sizes. I'm not sure why this occurs. Our rigs ended up around 12Mb in size.

2.2 Blend Shapes

Blend shape deformers enable you to deform a nurbs or polygonal object into the shapes of other nurbs or polygonal objects. You can blend shapes with the same or different number of nurbs CVs or polygonal vertices. In character setup, a typical use of a blend shape deformer is to set up poses for facial animation. It is said that unlike the other deformers, the blend shape deformer has an editor that enables you to control all the blend shape deformers in your scene. It is possible to use the editor to control the influence of the targets of each blend shape deformer, create new blend shape deformers, set keys, and so on. (Alias & Wavefront, 1999)

However, Moore (2001) says that when you add up the number of phonemes and emotions required to create a believable talking head, you soon realize that blend shapes become impractical. One character might have a minimum of six emotions, 16 phonemes, and a bunch of facial movements such as blinking, breathing, and raising an eyebrow. Blend shapes require huge amounts of modelling, and also huge amounts of data storage on a chosen gaming platform.

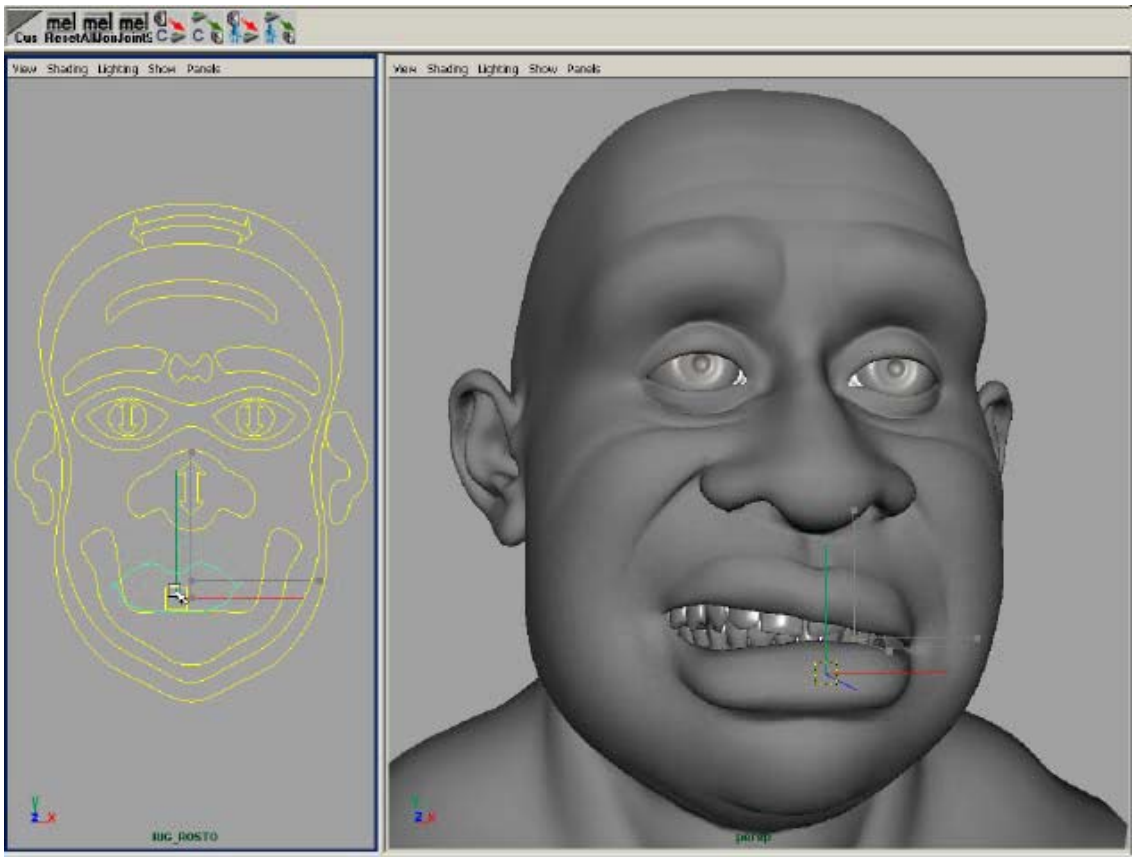
2.3 The Interface

As far as the User Interface is concerned, there are a few choices as to what to use as well. One is to use a shape driven interface, where the parts of the body are represented by simplistic shapes that are dragged around to form the expression. The other one could be using sliders from 0 to 1 for every part of the face, which blend between each other and form the desired emotion. The following figure shows how this was achieved in the Getaway using sliders. (Moore, 2001)

Figure 2.2 – The Getaway's Blend Shape Interface

A shape driven interface was used in "The Plumber's Dream" project (Antropus, 2005). Although it is mostly a matter of taste which interface to use, a shape driven one would be much easier to control and would possibly offer more flexibility in representing emotions together with lip synch. Figure 2.3 illustrates the shapes that are used to drag around in order to move the desired parts of the face.

Figure 2.3 – The Plumber's Shape Driven Interface



In our case, we want to create a basic skeleton for the face that could possibly be reused multiple times on other heads. Using Blend shapes for detailed expressionism was said to be impractical and very space consuming (Silke, 2002). Also, Blend shapes are very model-specific and it might be impossible to use them on more than one head.

Consequently, using bones would be much more beneficial for this project. However, using as less bones as possible is one of the goals as well. There will be some compromise as to how well the expressions can be represented, but just as long as a descent outcome can be presented, it may be possible to take this project into a more extendible area, such as lip synch. Presently, it is very difficult to find previous research that would recommend one technique instead of the other. Therefore, at an early stage in production the modeller needs to ask himself; what do I need to accomplish or to show the people? Most of the times, it might be a matter of taste. However, there may also be limitations to the technology being used. Imagine having to animate 500 characters' faces, it is not a job to do by hand. Therefore, in our case the cheapest and quickest method should be used, and that will be using bones.

2.5 Scripting Concepts

Creating such a system in Maya, gives the opportunity to explore vast areas of its scripting capabilities. Ewert (2002) states that MEL has a lot of qualities that are similar to the C programming language, and not as much similar to the Commodore BASIC derivative that he learned. He also said that based on his experience, any knowledge of C helps a great deal when learning MEL. Any C++ extensions to the language, e.g. object-oriented coding, constructor/destructor methods, and overloaded functions, are not at all applicable to MEL.

A major feature for this system that could be beneficial for modellers and animators, would be setting up weighting for each character they design, using a scripting approach. To achieve this, there are two approaches that could to be taken into consideration. One could be to use a single, but “well tested” bone structure. Nevertheless, the complexity and benefit of using bones comes at the weighting stage, for instance being able to transfer weights from one template model to another. However, just as long as the UVs are laid out the same, the weights can be transferred, even if there are a differing number of points. There could be a number of stages that could help out an animator. As mentioned above, one stage would be to be able to transfer UVs from a working setup model to a new model. Another stage could be to tweak one or both of the following two stages:

- Tweak the UVs of the new model to fit as best as possible within the template's UV space.
- Allow interactive movement of the bones into a suitable position for the new head. This is basically a User Interface task, with controls to simplify the selection and movement of bones and provide another user interface for previewing "ghosts" of both models.

Using Maya or any other major 3D package, there arent many techniques to that can achieve a satisfying facial expression system. Usually, most of the systems contain a UI that will allow the animator to play around with the parts of the face, in order to represent some kind of feeling for his/her character. A few of those techniques were evaluated previously. However, a basic bone structure should be build by hand, where

the UVs, weights and joints are properly laid out for animation. Using MEL script it would be possible to duplicate any given bone structure to other heads along with the UVs and weights. An interface could allow the selection of models and be able to represent some kind of emotion on each character separately. The interface that will be used to do the expressions is clearly a matter of preference, using sliders or a shape driven one.

3. Implementation

As mentioned previously there are many sources that need to be considered, in order to achieve a descent facial animation. Mainly, scientific research, as well as artistic background is necessary. So where do we go from here? It is assumed by now that using bones will be beneficial, since a bone-driven system could be reused in other modelled heads. In order to create a functional and robust facial animation system using bones, some steps need to be carried out in sequence, in order to avoid overlaps, as well as fatal drawbacks.

3.1 Step 1 – The Model

The model on which the bones will be applied needs to be in some way suitable for weighting. Most importantly, the edges around the mouth need to be forming some kind of circle around it. Also, it would be nice to have the same amount of vertices at the top and bottom of the lips, especially on the sides. This will make life easier when it comes to applying the weights for an open mouth.

In our case the model was taken from a student doing an MA course in Computer Animation here in Bournemouth. Kostas Strevlos, who generously offered to give a roughly-modelled head with texture. However, as mentioned above the area around the mouth had to be changed. This could allow lip synch and a nice good looking rig. Figures 3.1 and 3.2 illustrate how Osipa (2003) considered modelling his mesh in order to achieve a good looking smile.

Figure 3.1 – A smile's Width and Depth

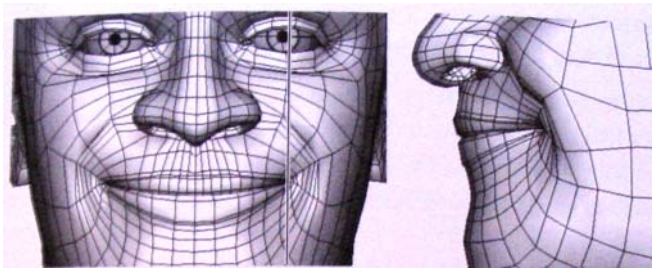
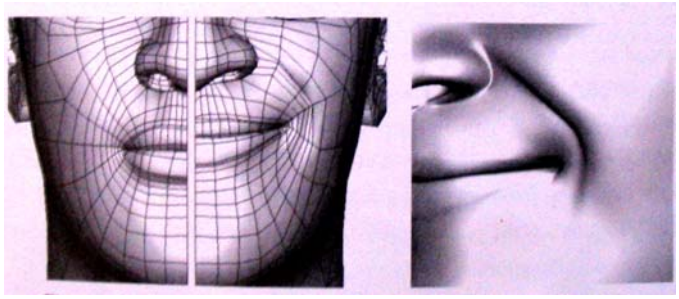


Figure 3.2 – A smile's Height



In our case the given model had to be changed and figures 3.3 and 3.4 illustrate the adjustments.

Figure 3.4 – The Mesh before the Adjustments

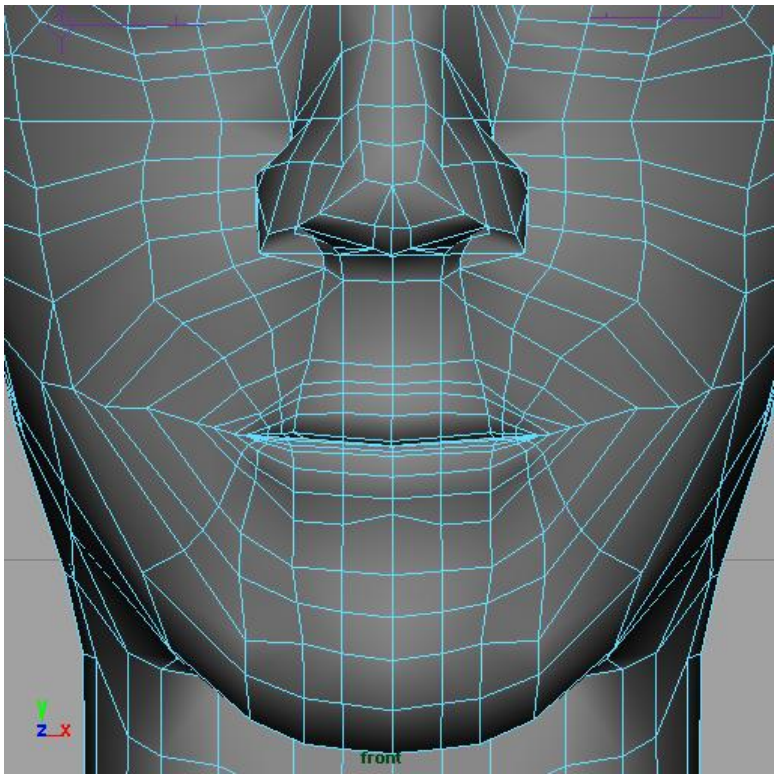
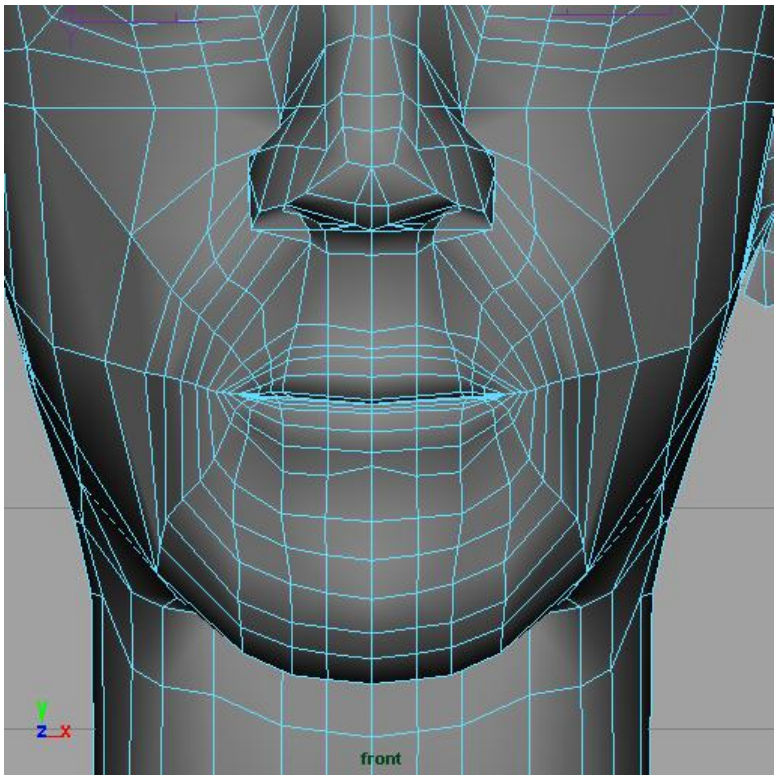


Figure 3.4 – The Mesh after the Adjustments



3.2 Step 2 – Laying Out the Bones

Properly laying out the bones before proceeding to the weighting will save time a lot of time. It is necessary to think about what a head does, and even though we all have a head of our own, it is hard to remember every single expression. However, it is understandable that every expression has a blend of another. This means that each bone will take part in probably more than one expression. In order to do that, the following guidelines may be considered for such a project:

1. Put as less bones as possible
2. Lay out all the necessary bones before proceeding
3. follow an existing template

Osipa (2003) illustrated the following neck template in figure 3.5, which is not too far from the one used for this system.

Figure 3.5 – A Basic Neck Structure

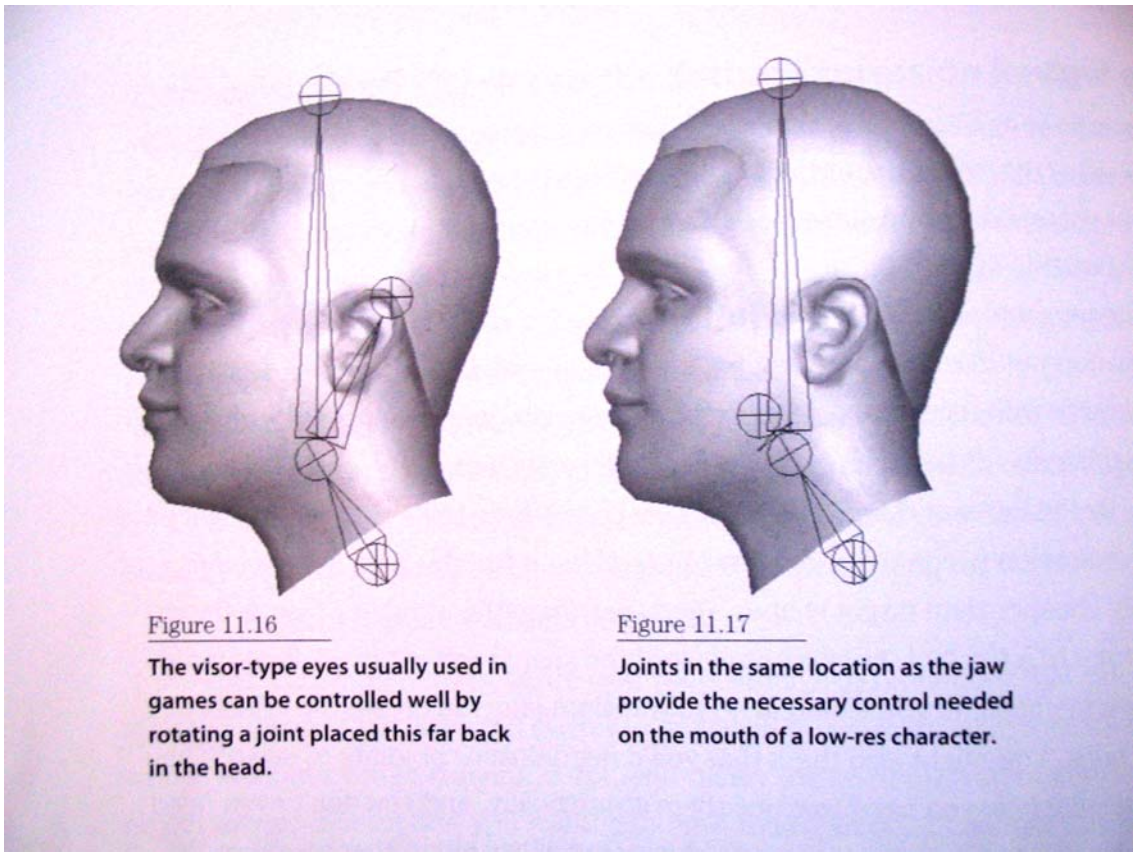


Figure 11.16

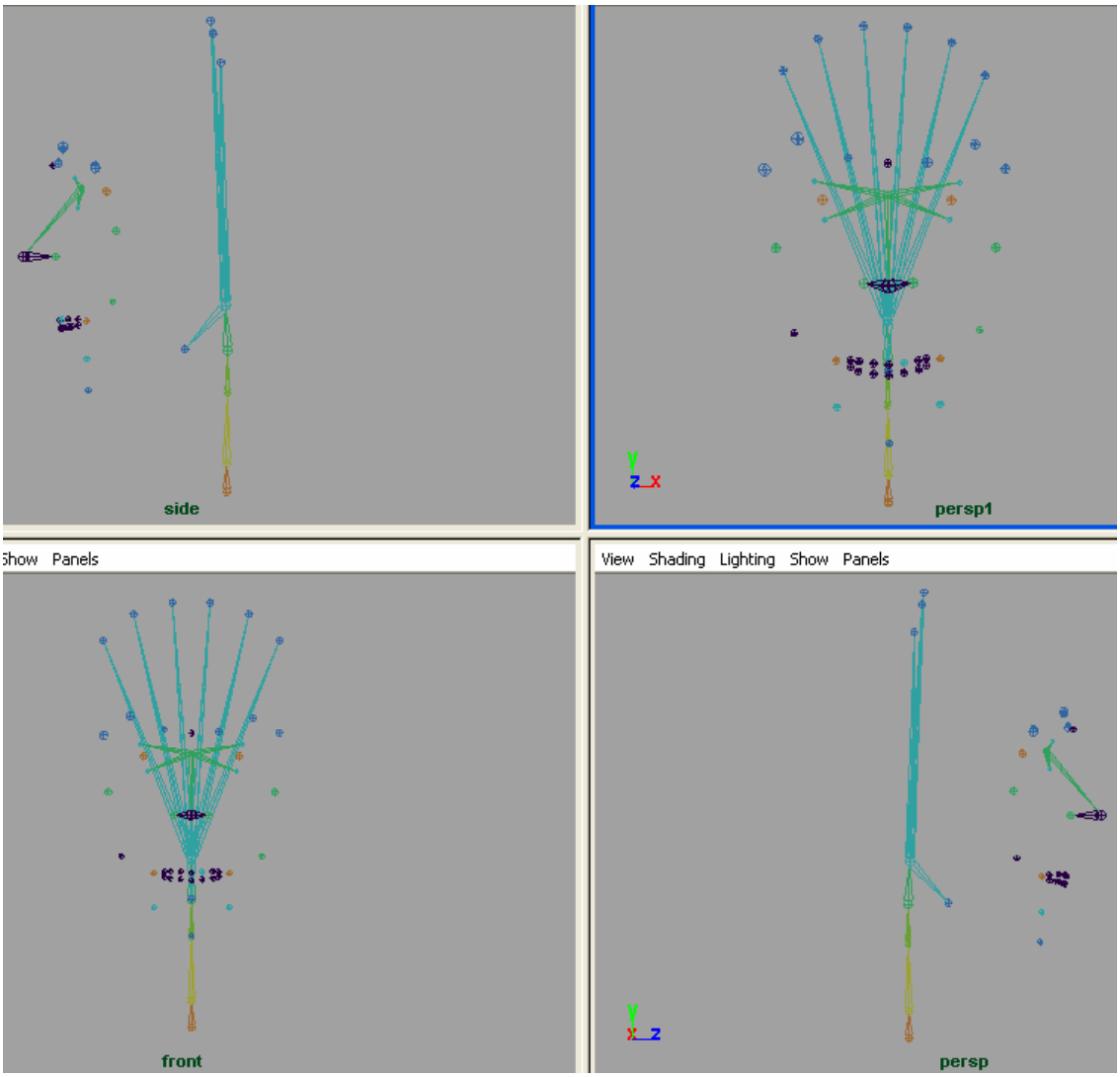
The visor-type eyes usually used in games can be controlled well by rotating a joint placed this far back in the head.

Figure 11.17

Joints in the same location as the jaw provide the necessary control needed on the mouth of a low-res character.

Consequently, the following bone structure in figure 3.6 was developed and adjusted to the model, which was influenced by the Plumber's project mentioned earlier. The plumber's project made use of an enormous amount of bones that would obviously achieve more poses, but as mentioned earlier the purpose of this research is to develop a simple, reusable bone structure.

Figure 3.6 – A Basic Bone Structure for the System



The joints are grouped individually, such as Brow_Left, Mouth, etc, and then are constrained (Constraint > Parent) or driven by a key (Animate > Set Driven Key > Set) from a user interface that will allow easily to switch between the different expressions.

3.2.1 The Weighting

Applying weights has never been enjoyable. It requires a lot of patience and time just to achieve a simple expression. This is why the modelling needs to be appropriate for weighting before doing anything else. Also, it would be advisable to decrease the amount of vertices as much as possible and work with a smooth proxy model. Using the weight paint tool would be good to start with applying basic weights, but then it would be recommended grabbing a series of vertices and edit them using the component editor

(smooth skins). Every vertex will have to have a total of 1.0 in weight that can be distributed among different bones.

3.2.2 Applying Constraints and Keys

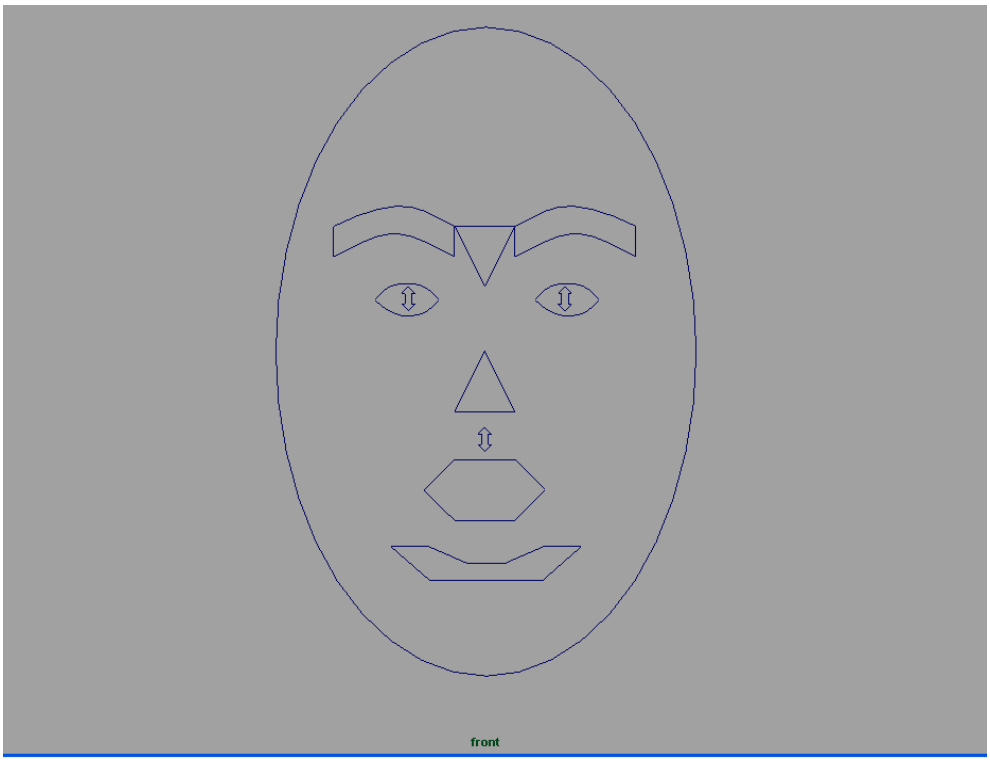
Applying constraints is necessary since the system makes use of a User Interface (UI). A shape driven interaction between the bones will allow the blending of various expressions. When it comes to applying a key driven system there may be a few surprises. Usually when it comes to using many keys together, some keys might get lost and cause undesirable outcomes. In order to overcome this rare problem, a .MEL command can be used, such as: `setKeyframe -at input[6] -v 0 blendWeighted372;`

A very useful tip to mention at this point would be that in order to rotate the jaw, together with the bottom lip, it is needed to use a constrain and a key together. This can be tricky, as many parent, and blend weights take place at once, and the order is extremely important. When applying a driven key to a constrained bone, a **pairBlend(n)** node is created that may need to be changed from 0 to 1 in order for an expression to work properly

3.3 Step 3 – The Interface

The interface developed for the system was drawn with curves in Maya and most of the shapes represent a part of the head or face. Those shapes are given some translation limits and are connected to bones using driven keys. But where are the parent constraints used? They are applied to locators around the head that take part in the movement of the bones. Locators were place for the rotation of the jaw and movement of the lips. It is also important to freeze the transformations or in other words set them all to 0, before applying any keys. Figure 3.7 shows the interface that drives the system.

Figure 3.7 – The Interface



The interface allows the manipulation of all the bones in order to achieve simple expressions, such as anger, surprise, etc…

4. Further Research

In the future it would very interesting to extend this project to a system that would generate the weights automatically, once the bones have been applied onto the mesh. This could theoretically be achieved using locators all around the head that would calculate the distance between each bone and therefore apply the weights appropriately. Conceptually, this should be achieved since it could be assumed that a head is symmetrical, although each face has its own distinctive characteristic that makes it exceptional. This system could use an interface made in MEL that would import the bone structure and offer a number of functions used to calculate the distances between selected bones, and have more functionalities to play around with weights. This would save time and money for the industry.

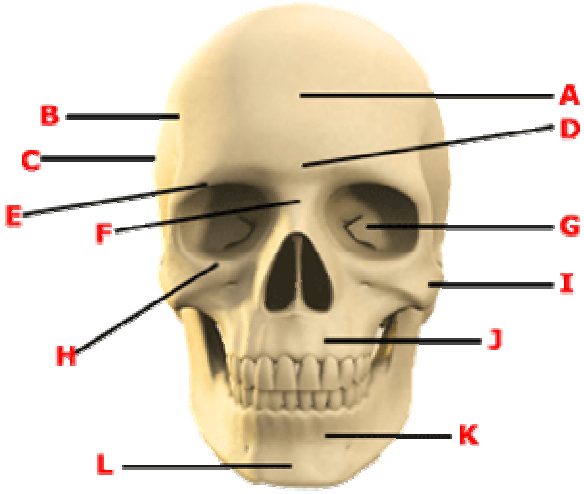
5. Conclusion

It is unfortunate that in the past not much research has been conducted in order to deliver a simple bone driven system that could allow reusability on more than one modelled head. Therefore, it might be considered a matter of taste whether to use bones or blend shapes for facial rigging. Although, it could be said that using bones might be a lot more beneficial, the whole concept of facial expressionism does rely on more than one source, which could be artistic or scientific. In order to understand how the face works, it is needed to have an artistic eye, to capture expressions, as well as the ability to understand what is behind the functionality of those expressions, such as muscles and bones.

Many projects have made use of bone driven systems, but few mention how everything was done. This causes problems to people who either don’t know how to create a simple system or to the ones who would try to think which method would be best to use. However, bones can be very tricky and quite difficult to manipulate, but it could surely save some time when it come to doing a large number of expressions. This system achieved to reach a decent outcome, by following some simple steps which emerged from the development of this project. These steps included the modelling of a head, the bone setup and the interface.

Appendix A

Bones



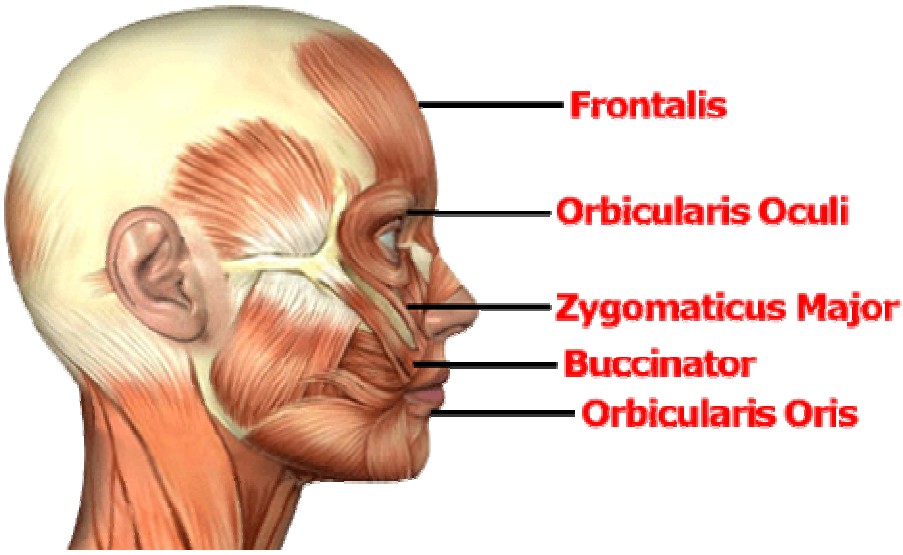
A. Frontal Bone: Makes up the forehead. Extends from the top of the eyes to the top of the head.
B. Temporal Ridge: A place for muscle attachment on the sides of the frontal bone. Responsible for creating the square shaped appearance of the skull.
C. Parietal Bone: Extend backward on the top of the head from the Frontal Bone until the farthest point at the back of the skull.
D. Nasion: Point between the eyes where the frontal bone meets the nasal bones.
E. Supraorbital Margin: Top of the eye orbit. It is part of the frontal bone which lies directly under the eyebrows, hanging over the eyes.
F. Nasal Bones: Create the shape of the upper portion of the nose.
G. Orbital Cavity:Large hole where the eyes are located. They are much larger than the actual eye.
H. Infraorbital Margin: Bottom of the eye orbit. It is the upper portion of the cheekbone.
I. Zygomatic Bone: Known as the cheek bones, they help comprise the infraorbital margin. When smiling the tissue collects in front of the zygomatic bone, which causes a puffy cheek.
J. Maxilla: Two bones which form the upper jaw. Attaches to the cheek bones and forms the nasal opening. Upper teeth are attached to the maxilla.

K. Mandible: The lower jawbone. Defines the contour of the lower face. The teeth provide an easy guide to determine the movement limits.
L. Mental Protuberance: Tip of the lower jawbone. Forms the chin.

The head can be evenly divided into two parts, by drawing a line to the centre of the Orbital Cavity. This will allow a proportional development of a human like head. (Fleming, Dobbs, 1999)

Muscles

There are more that 20 muscles that move the skin, lips, nostrils and eyelids in different facial expressions. (Grine, 2002)



Frontalis: It inserts into the skin of the eyebrows, and draws them upward, thus wrinkling the skin of theforehead.

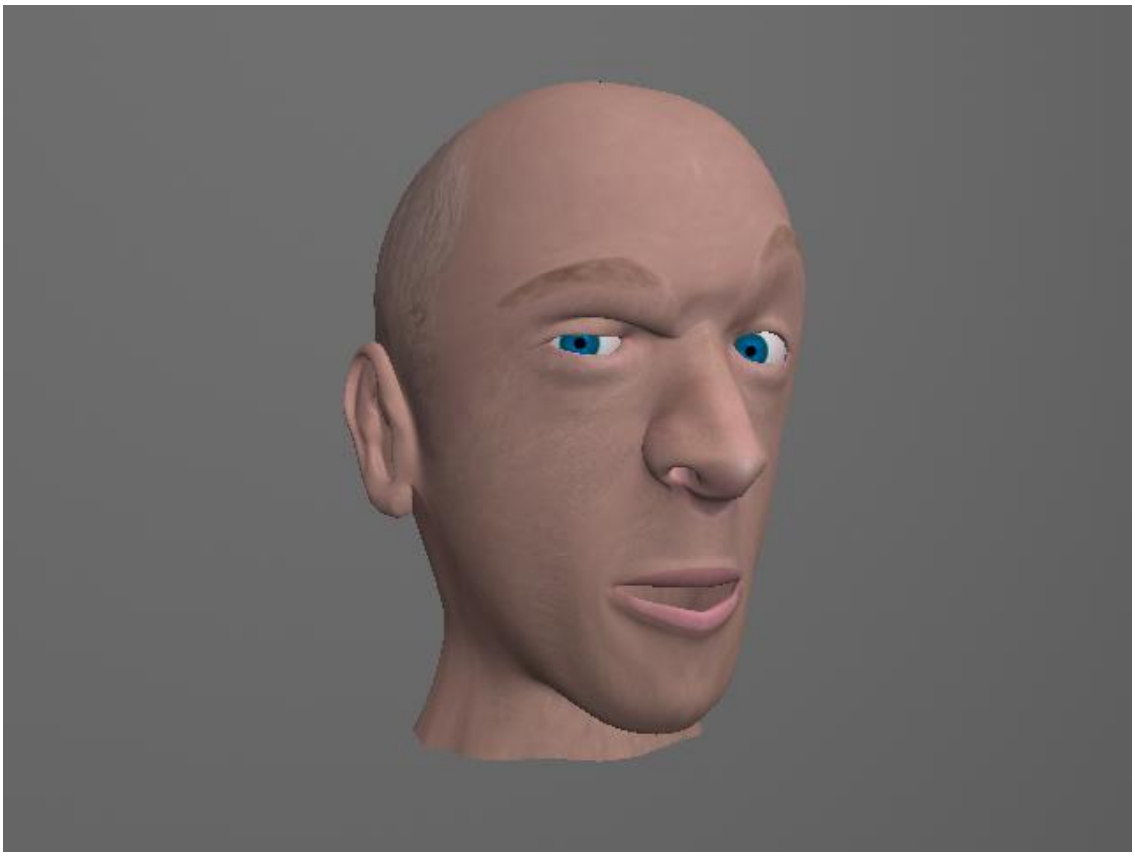
Orbicularis Oculi: It consists of three parts, and each has a different function. The Palpebral runs in the eyelids, lowering during blinking and voluntary closing of the eyes. The Orbital runs around the periphery of the eyelids, and acts during forceful closure of the eyes. The Lacrimal runs from the crest of the lacrimal bone to the medial part of the eyelids, and compresses the lacrimal sac.

Zygomaticus Major: Arises from the front of the Zygomatic Bone and inserts into the corners of the mouth. It draws the corners of the mouth upward, as in smiling.

Buccinator: It inserts into the corners of the mouth. It increases the rigity if the cheek, and is, therefore, important in mastication.

Orbicularis Oris: Encircles the mouth within the lips. It closes the lips and, compresses them against the front teeth, and purses them, as in pouting or kissing.

The Outcome



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