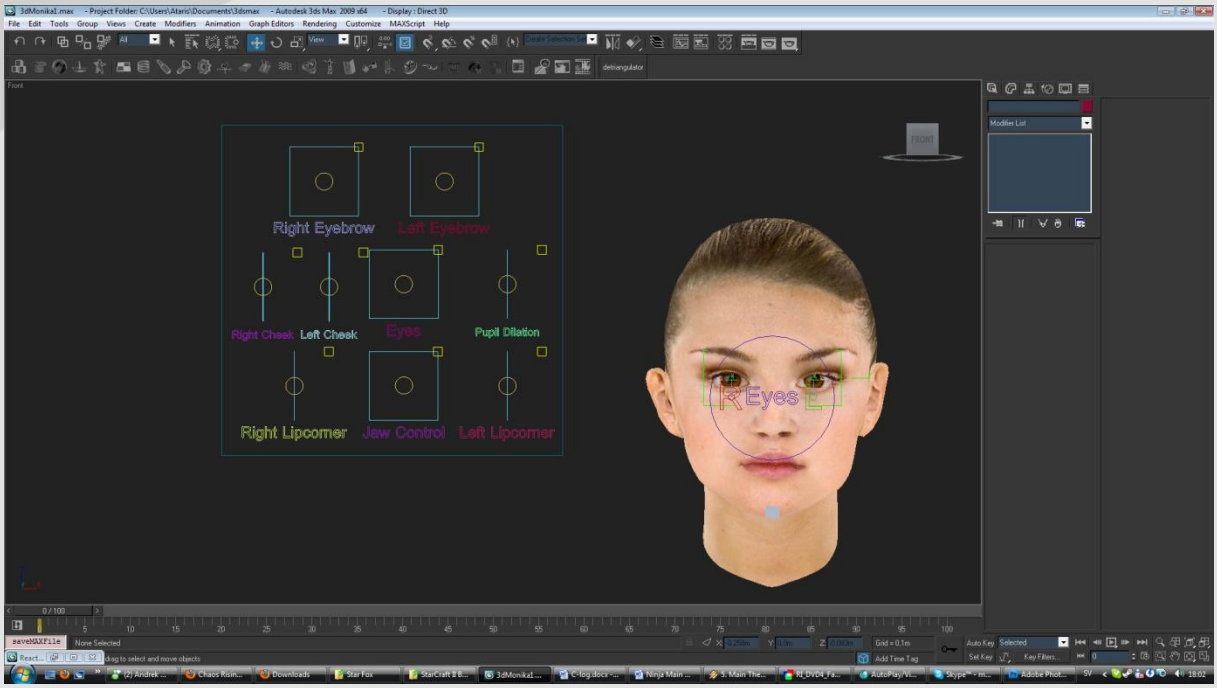
Högskolan på Gotland
Gotland University

Facial Rigging and Animation in 3D

From a videogame perspective



Högskolan på Gotland/Gotland University
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Examination Report
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Facial Rigging and Animation in 3D

Synopsis

What are some of the methods for rigging and animating a face in 3D and which method is preferable when and under which circumstances?

In this report I will examine a few of the different methods available when rigging and animating a face in 3D. I will be working mainly with Autodesk 3D Studio Max so some knowledge with it is preferable to fully understand the process. At the end of the report I will look at the positive as well as negative aspects of each method as well as which method is preferable in what kind of production or with which assets.

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Acknowledgements

First of all I would like to thank my supervisor, Andreas Wahlman. He's been a great help and without him I would probably never have managed to finish this project at all. I'd also like to thank one of the other teachers at my school, Jakob Rogert Berglund, for helping me remember how close and imminent the deadline for this project always was, and how key proper planning is if you want to succeed. I would also like to thank my family and friends for their support.

Introduction

This report details the process that I went through when researching and examining the different qualities offered by the different methods for facial animation in 3D.

I will be looking at what will be best from a game-making perspective and attempt to draw a conclusion of what methods are best time-wise for the best quality possible. I will also attempt to draw a conclusion of what methods give the best quality and which method is simply the fastest one.

I will determine this through information gathering, research and testing through practical means. The goal is to model and rig a face using the most relevant methods available to me, in order to see which method gives the best detail, what is most time efficient and what method is best suited for what kind of production. This will all be looked at from primarily a video game perspective as I do not have enough experience in full CG motion picture to determine exactly what is most efficient and valuable there.

For practical testing I am using Autodesk 3D Studio Max 2009[9], since it is the program I am most used to working with and is widely used throughout the video game industry.

Main Body

Getting Started

Here I will describe the method I used in the project to achieve the results I wanted and planned for.

I knew that I was going into relatively unexplored territory with my project, so my first goal would be to gather any and all information I could. I anticipated most of my information would have to be from the information. I spent a few days looking around, but I never really came across any substantial sources of information around facial rigging and animation. The best I could find was CGTalk's facial rigging thread[1] and Paul Neale's tutorials[2]. Most of the information seemed restricted to purchasable DVDs and books. I kept on looking a lot, with a few more results, but overall with too little information to carry on with the project. I arranged for a meeting with my supervisor to see if he could help me and got a time scheduled the week after.

Since time was passing I was forced to start if I were going to have the time to complete everything I wanted in the project. I started modeling a face that I could use for rigging and animation. I searched around for how to create a face that would animate good and found a good tutorial at Computer Arts[3]. This proceeded relatively painless and I had few issues with the actual modeling. The most challenging parts turned out to be the eyes and the ears, but nothing that wasn't solved with some hard work.

Next, I went to the previously arranged meeting with my supervisor, to see if he could help me find information surrounding the subject. He told me about his experiences with facial animation and where I could look for more information surrounding the subject. He also supplied me with a book called Creative Essence: The Face, which greatly described in detail how to model a photorealistic face as well as an example model that I could use in my project. He told me how there were two main methods of facial animation; using bones and using Morph Targets. I will attempt to explain the basic mechanical differences between the two.

Skeletal Animation (bones)

Bones are objects in the 3D space that have a defined influence on vertices. They are constructed in a series, linked to each other, forming a hierarchy. The vertices that make up the 3D mesh are then "weighted" unto each bone, with each bone having a different percentile of influence of each vertex. A vertex can be pulled by multiple bones. Each bone is defined by its shape, place in the hierarchy, scale, position and rotation in the 3D space. Every bone higher in the hierarchy influences the bones below it. For instance, the full torso is higher in the hierarchy than the arm bone, so moving or rotating the torso bone will automatically influence the arm bone as well. The bones are then animated and rotated in the 3D space, which in turn will drag their designated vertices with them (according to how the user has weighted them to each bone). This simulates the movement of the actual model. You can read up more on Skeletal Animation here. [4]

Morph Targets

Morph Targets is the alternative to Skeletal Animation. Morph Target animation is essentially a series of duplications of a model that are then modified into a different, desired shape. The program will then either interpolate the difference in position of each vertex according to their number and move them accordingly, or switch between them, the former method being the more common one as it creates the smoothest animation. This gives per vertex precision in animation, but is generally a more expensive way to animate, both time and performance wise, due to technically having to animate each individual vertex you want moving. This makes the method impractical for animating anything other than cloth, skin and facial expressions. It should be noted that Morph Target animation can still be assisted by bones for larger movements (such as the jaw on a face) to save time and larger movements in the animation. Morph Targets also makes for good exporting when it comes to animations, since many 3D applications handle bones differently, while there's only a few real ways to handle Morph Targets, making the animations compatible with a lot of different applications out on the market. You can read up some more of the basic information surrounding Morph Targets at this site. [5]

There are also other types of more experimental animation that I hoped to get time to experiment with. Mainly muscle based skeletal systems and Shape defined animation. Muscle-based Skeletal Animation uses bones just like regular rigs, but tries to simulate the muscles in the face. Shape defined animation uses Shapes and Constraints to animate instead of bones.

All of this provided a great start for my project, but I still lacked some essential information.

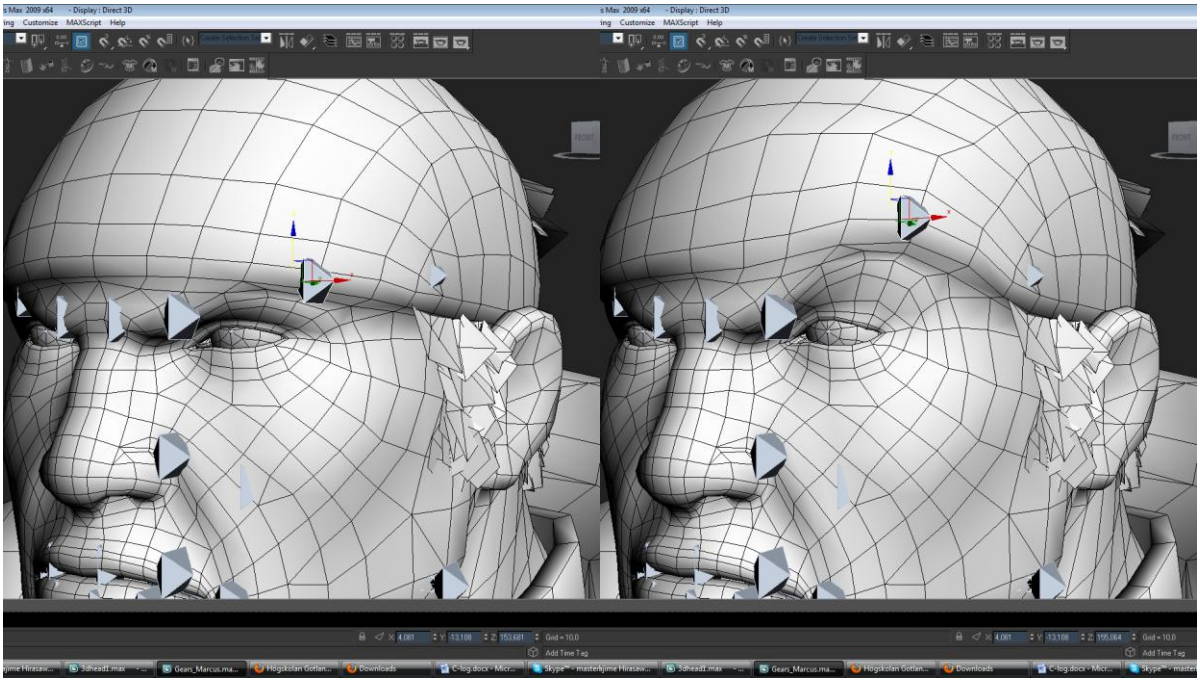
While searching for more information I set up a rough plan of how the project would look for me. Considering the lack of information I had found and the fact that this was for me, unexplored territory, I had to be generous with backup time, due to the amount of issues that could fall upon the project. I could fail to find any new information, get stuck on an issue without any solution or have regular crashes without any real backup plans or nets to fall back on. This made a good planning key to the project. I set up a rough outline like this:

- Two weeks for research
- One week for model assembly
- Two weeks for Skeletal Animation
- Two weeks for Morph Target
- One week for Experimental Animation types
- One backup-week

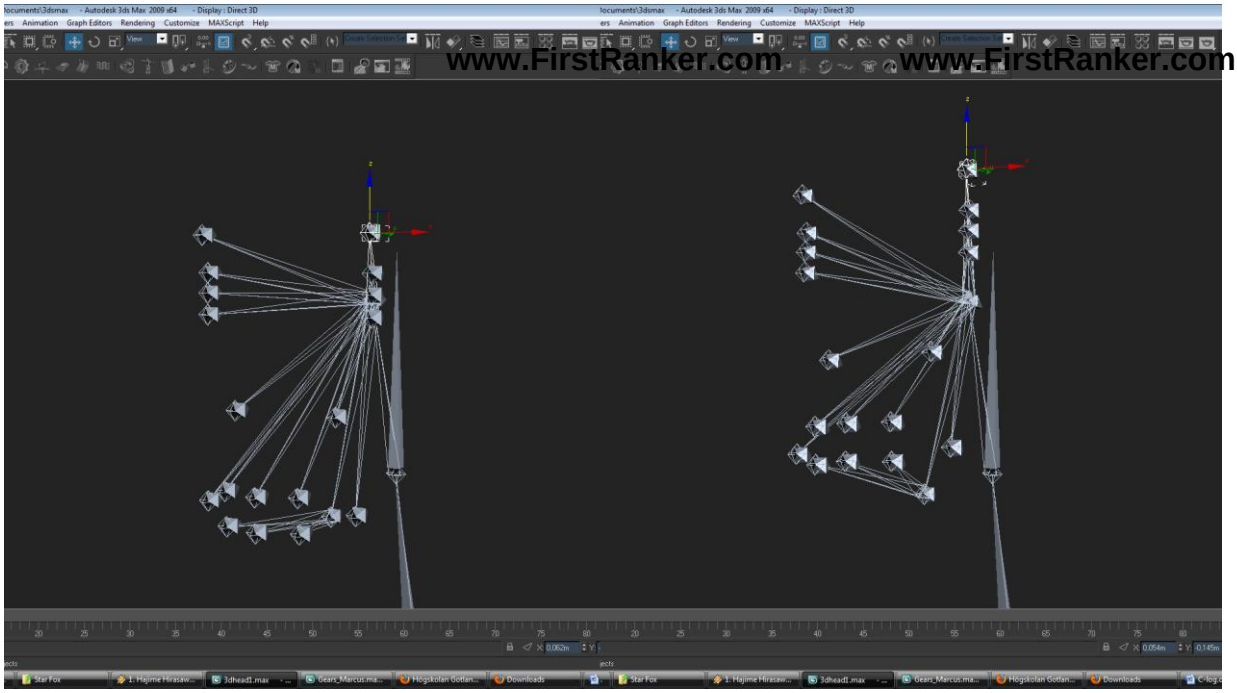
Basic Skeletal Animation

While spending some time doing research, I still had to make sure the project proceeded according to plan. I had enough information to begin on the Skeletal Animation system, based on the model I had made the previous week. I wanted some more references to work from to decrease the risk of getting stuck, building something completely incorrectly or come across other big obstacles that could cause a too big waste of time. After a lot of searching I managed to find a good bone system to work from, namely, the one used for Marcus Fenix in the Gears of War series. The model can be found on UDN, where I downloaded it from. [6] Shortly after I began construction of a system that closely resembled the one used by Epic, until I ran into some issues. [Picture 1]

I had an identical type of hierarchy when compared to the Fenix model, but for some reason my rig reacted different to movements and rotation. What followed was a lot of troubleshooting. I spent a lot of time looking for a solution at the different pages on UDN[7], but to no avail. I spent more time just using different search engines to hopefully find a solution to my problem, but I found nothing that resembled my problem. I contacted my supervisor to arrange another meeting, to see if he could help me, and if not, what could be done instead.



Picture 1.1: This is the reference model I used. On the left picture the bones are untouched and on the right picture I have raised the eyebrow bone. The rig reacts as it should and no problems show up. This rig has same kind of hierarchy as my own facial rig I constructed.



Picture 1.2: The first facial rig I built. On the left picture the rig is untouched. On the right picture I have attempted to raise the eyebrow bone, but the entire rig reacts to the movement and the whole face is consequently raised, unlike on the reference model. It should be noted that both the reference rig and this facial rig I built has the same kind of hierarchy.

While waiting for the meeting I spent some time looking into other sources of information regarding facial rigging. I was thinking I could hopefully solve this on my own and not have to waste more of the precious little time I had. I wasted a lot of time and effort on things I gained little from.

If found something that seemed interesting though. Something called Puppetshop that I will hopefully get time to take a closer look at later in the project. It's a free plug-in for 3D Studio Max that seems to focus on quickly setting up rigs for characters and creatures. I have not found any support for facial rigging in this tool, but it might be worth keeping an eye on all the same.

FaceFX is another popular and widely used method for rigging faces. Its main purpose is lip-synching and preset expressions for character. The only real work that needs to be done in this case is rigging the character according to the specifics set up by the tool. This eases the work a lot, but it might not be usable for all kinds of characters and you might want to keep a personal touch for each of your characters, in which case rigging and animating by hand might be preferable. [11]

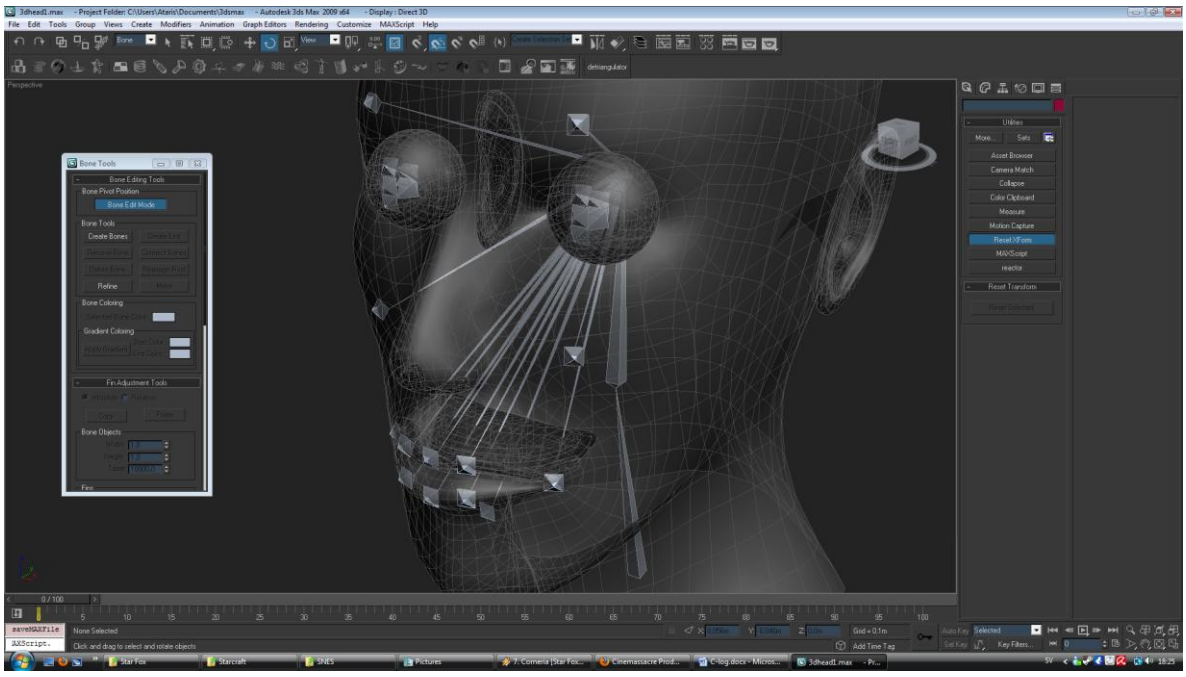
Luckily though, my supervisor did have time to meet me within a short timeframe. We sat down and discussed the matter, trying to solve it. Eventually we did, but the cause of the problem is still unclear to us both. The rig is identical to the reference in every way we can see, yet it behaves completely different. Our conclusion was that there is some kind of extra scripting or coding involved, related to the engine used for the Marcus model. After having fixed the issue we spent some time looking at and discussing GUIs for facial rigging. There seems to be two dominant ways to rig a GUI.

A GUI is a graphical user interface that helps the animator to animate the face for any sequences needed in production. It generally works best with Morph Targets due to their very nature of being completely value-based.

One focuses on replicating the actual vocals for the mouth, using a lot of sliders, and then forming the movement of the jaw and the lips through a string of combinations of tunings. This is probably the more advanced version and gives the animator a lot of control over the mouth. It isn't completely as user friendly as the other method however. This method has a bit of an advantage when it comes to speech animation, simply due to the fact that you have to mimic the sliders to the words that are supposed to come out of the character's mouth. This method generally requires a lot of different Morph Targets to achieve all the different movements of the mouth, but the quality of the mouth animation can be considered worth it for larger scale productions aiming for high detail for say, a main character.

The other method uses control rods as well as sliders to set the different facial poses. This method has an advantage when it comes to facial expressions and other, more exaggerated poses, mainly because you have direct and individual control of each part of the face. This is usually a lot quicker to set up than the previous setup, since no specific movements of the mouth has to be constructed in the Morph Targets, meaning fewer actual Morph Targets are needed. It's also a bit more user friendly in that every single controller has a direct effect on the face.

I set out to finish my Skeletal Rig. By now I had lost a week to troubleshooting and was severely behind in the schedule I had set up. I knew that I always had my backup week, but I really wanted to spend that on looking into the other forms of rigging. The muscle based system greatly intrigued me and I really wanted to see if it could be useful in the video game industry. I consulted my supervisor a bit on how much bones without weights actually cost performance wise in a game engine. I was told that bones overall does not drive down performance any significant amount as it is the actual keys in the animating that does. This makes this option a lot attractive, I think. I went on to finish my Skeletal Rig with little issue. I had some minor troubles due to mirroring imperfections, which cost me a lot of time since I could not mirror the weights from one side of the face to the other without a lot of fixing. Overall I spent a lot of time with the actual skinning, but in the end, I got it all done with what I would consider passable results. [Picture 2]



Picture 2.1: This is the finished Skeletal Animation rig, with the model attached.

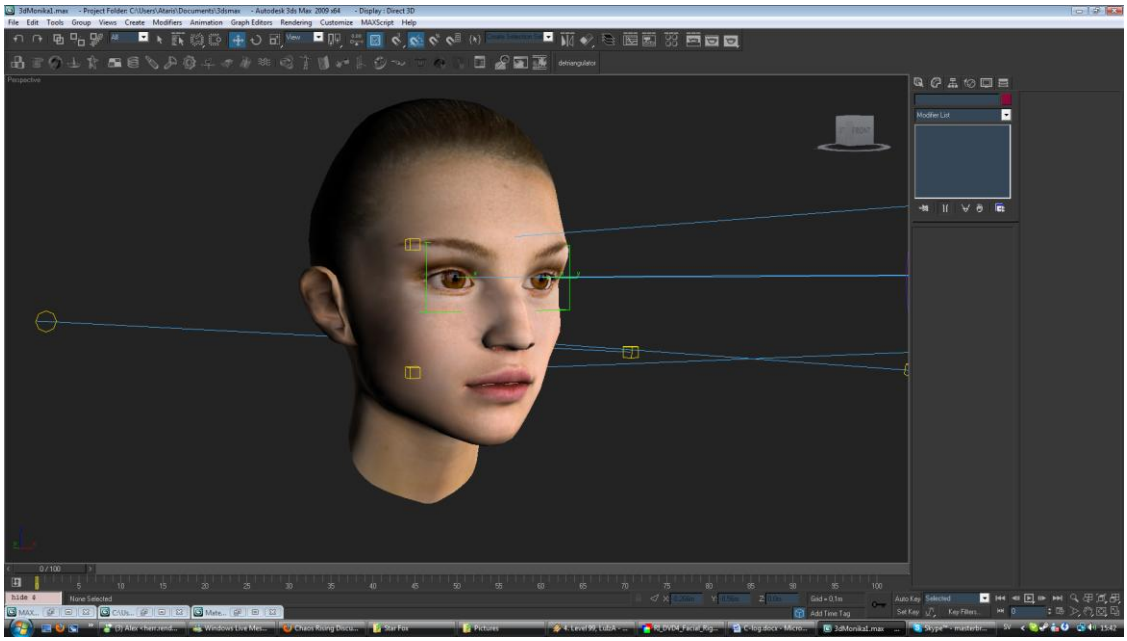
Morph Target Animation

By now I was done reading the source material provided by my supervisor. I extracted the model he provided me with and decided to move on to the Morph Target animation.

I came across a DVD part of the CG Academy series that focuses on Intermediate Facial Rigging.[8] If you have the resources, I can strongly recommend checking it out. I will attempt to mirror the techniques used there, as it covers Morph Target animation really well.

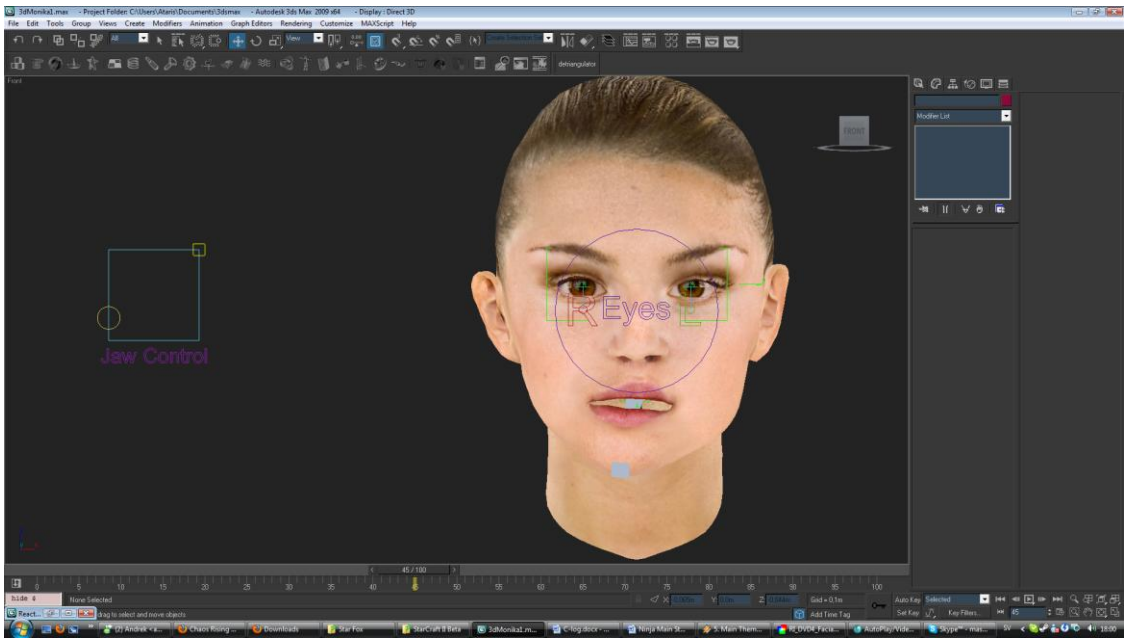
I started off as advised by the source material, with the eyes. I rigged the eyes using a combination of Point Helpers, Shapes and Constraints to create a control for where the character would be looking. The biggest issue that might show here is how the head bone affects the eyes. Due to the influence on both parts, unless you rig with helpers, they eyes might start twisting and turning to accommodate to the head doing so. What needs to be done is constrain the eyes to a particular axis using Helpers.

Next, I moved on to pupil dilation, something that's very hard to do using bones. Using Transform modifiers and some basic scripting it's possible to tie the size of the pupils to basic controllers and sliders. This is an extremely helpful tool for when you need that extra bit of detail on a character's face. It's something that's subtle but adds a great amount when you're creating fear, surprise and other drastic emotions. It's also something that's relatively simple to do. [Picture 3]



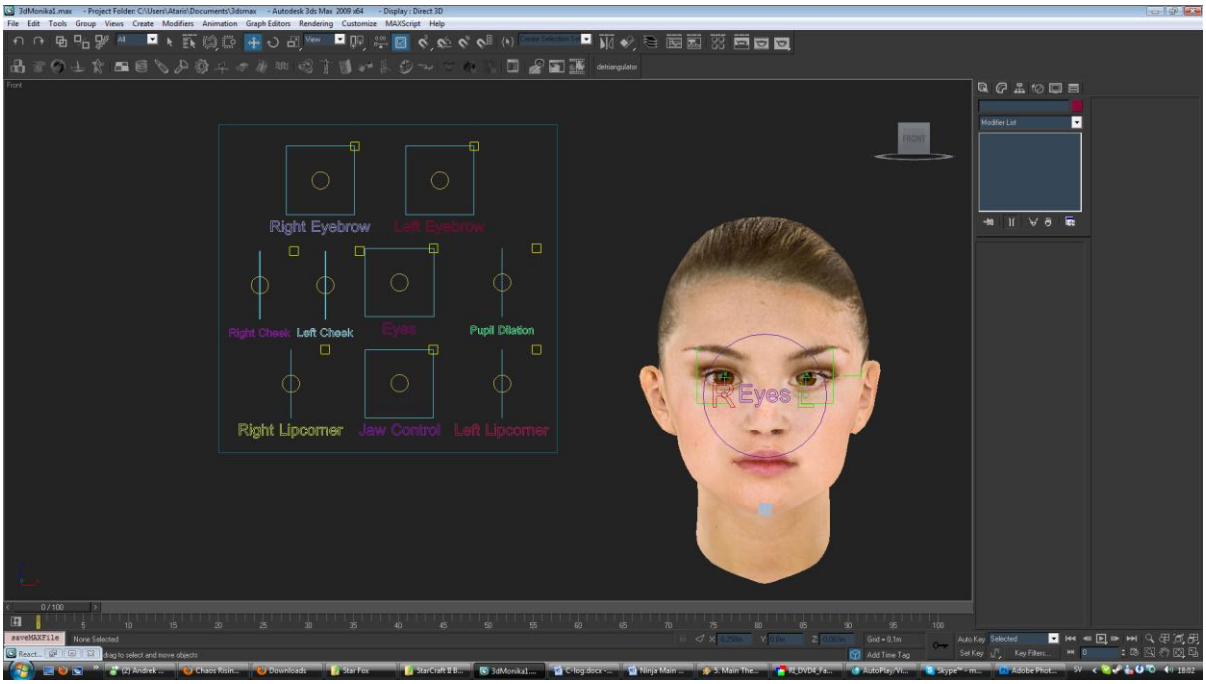
Picture 3.1: The eyes are now set up on the model. Both pupil dilation and direction can be set up using the controllers seen in the scene.

Since the jaw is something that's extremely hard to animate using Morph Targets due to its very nature(it functions anatomically exactly like a regular bone) I skinned it to a bone to save time and it's something that I'd recommend due to the sheer difficulty and time it would take to setup properly using only Morph Targets. [Picture 4]



Picture 4.1: The jaw skinned and set up to controllers. It can move along both the X and Y axis to what I considered the extremes.

Next I started constructing the Graphical User Interface that is used to control the Morph Targets. This is accomplished through a hierarchy of shapes, constraints, scripting and extensive use of the Reaction Manager. The main controllers will be Circle Shapes enclosed within Rectangle Shapes. Moving the Circle Shape will affect the percentage of each Morph Target active on that particular part of the face. For more advanced controllers, scripting will be needed due to the limitations of the Master-Slave system. Only one Master can control a Slave, for some controllers you'll want more than that. The actual GUI is thus only a 2D interface in the 3D scene, there for animation purposes and convenience only. [Picture 5]



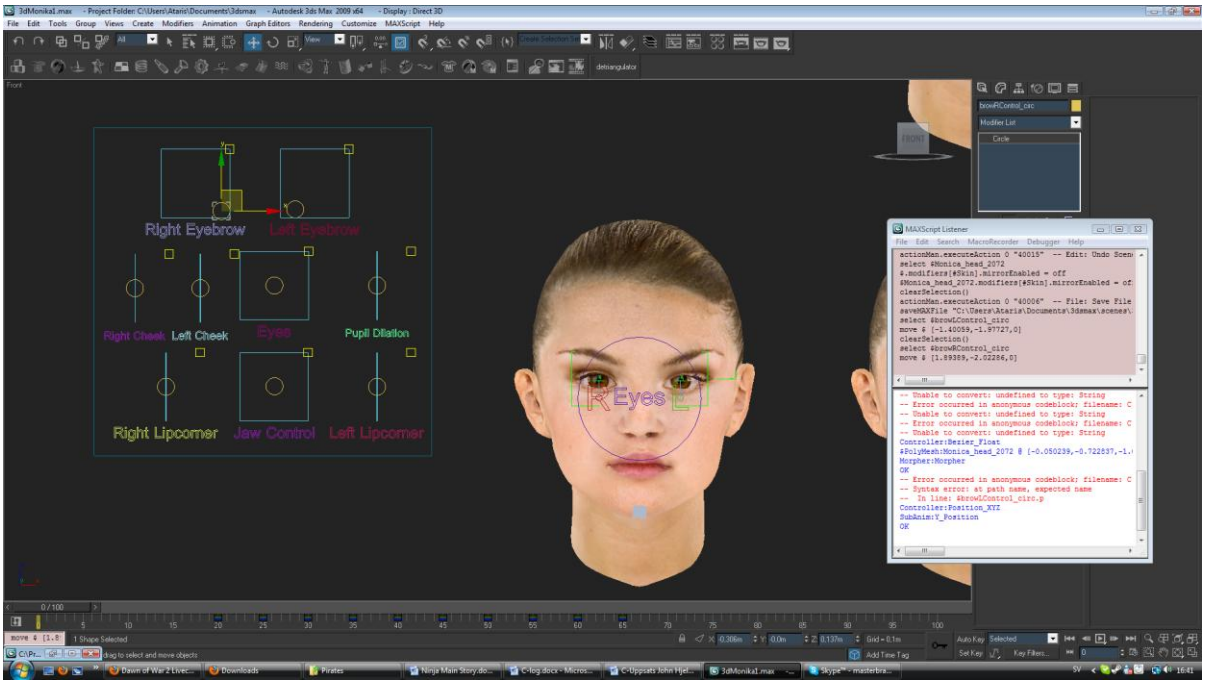
Picture 5.1: This is the GUI, all set up and ready.

I started off with my actual Morph Targets by copying the model head and modifying the vertices. I got hold of a script that would mirror Left and Right for me. Unfortunately the model I used was asymmetrical and as such, despite my attempts and minor adjustments I had to settle for once again modeling the Left side and the Right side individually and apart from each other.

I started with modifying the mouth and lips. I think the hardest part is keeping the correct and natural depth for the lips as they move. There is also the dilemma of how far you want to take each emotion. For the lips I made the corner adjustable, up and down in this case. This in unison with the Jaw bone actually gives most of the mouth movements that are needed. Due to the nature of this project I have not had incredible amounts of time and thus had to be satisfied with keeping it relatively simple.

Next I modified the cheeks to raise and lower depending on the expression that's needed, it's a small touch but adds a lot of movement to the face.

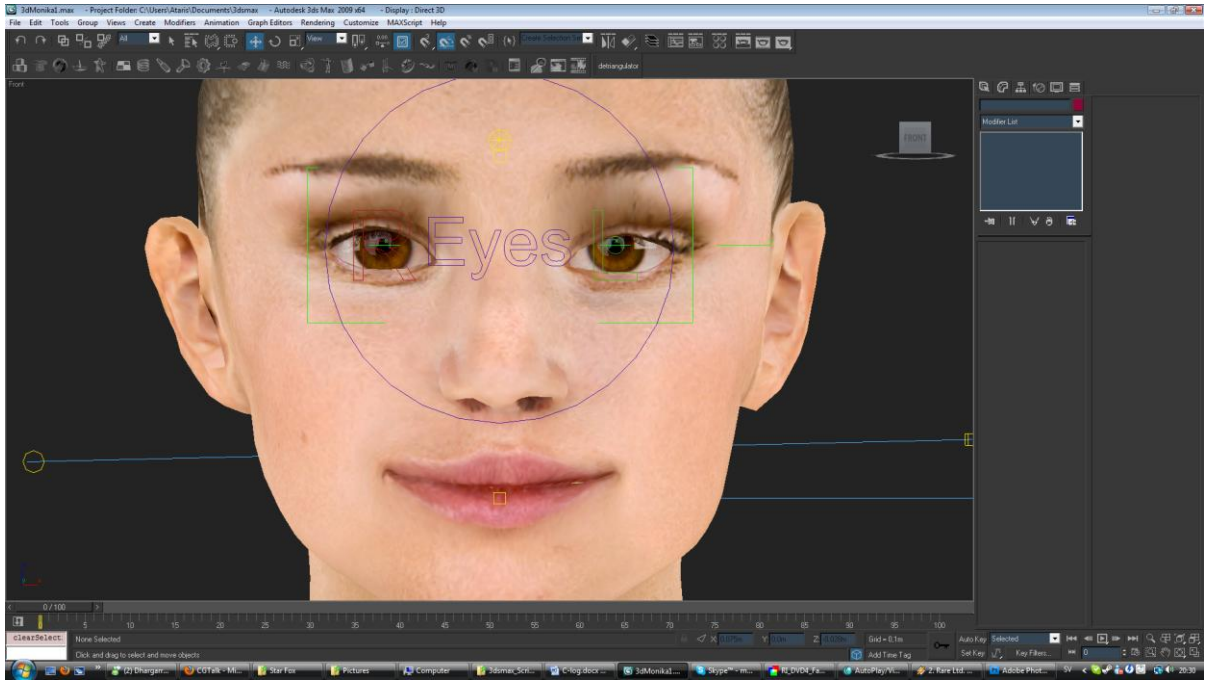
I continued on to the eyebrows. These needed a bit of extra attention due to the nature of Reaction Manager. There are basically 3 different setups, in detail level. Two, four or six Morph Targets, all depending on the level of detail you want. You could possible go with even more, but there'll be little you can't do with six Morph Targets. I rigged the eyebrows to the GUI using Float Values, since in its most basic and direct form Reaction Manager can only handle one Master per Slave, and to make fully functional eyebrow controls, you need more than that. I solved this using scripting, subtracting from the Morph Targets when moving the controller along the X axis.



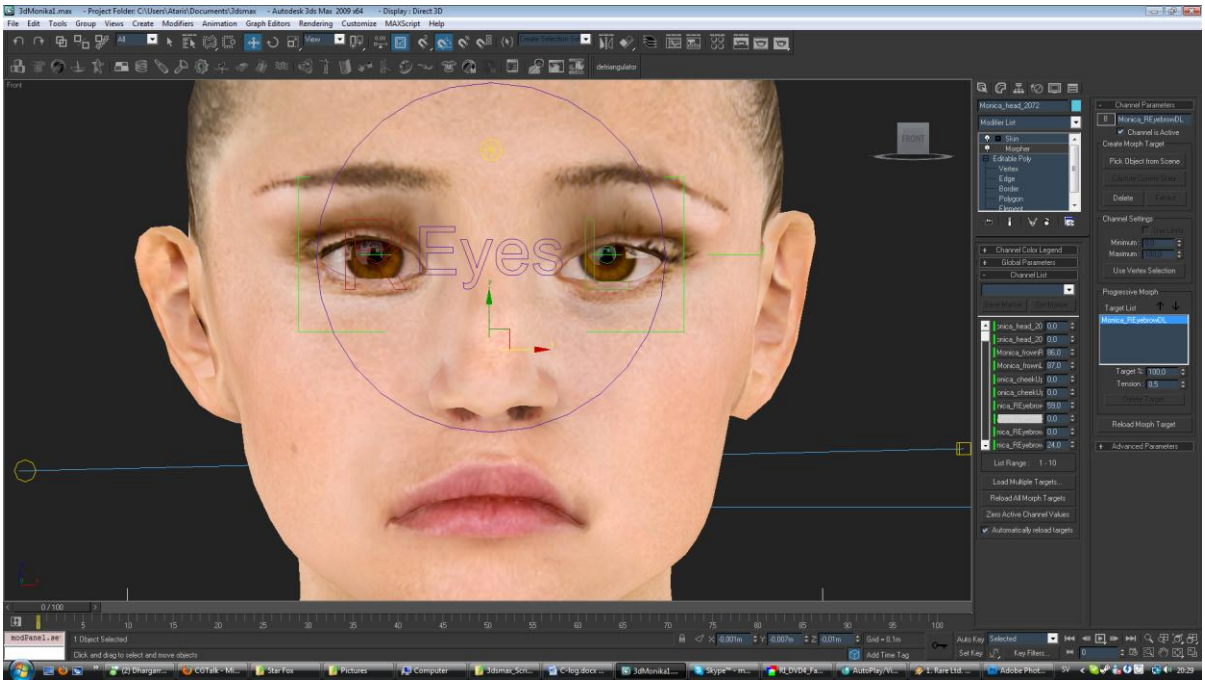
Picture 6.1: The eyebrows are rigged to the GUI. The more X axis decides what side of the eyebrows they are affecting, accomplished through scripting in combination of the Reaction Manager instead of just using only the Reaction Manager. This is due to limitations in the Master-Slave system used. The Y axis controls whether the eyebrows are raised or lowered. With this, the animator can very quickly set up if the character should be angry, sad or anything of the like.

Picture 6.2: These are all the Morph Targets used for the final rig and its

Next I went through a testing phase, pushing all the controllers to their extremes to see what would break and what would look bad or broken. If I can manage to fix the extremes, everything in between usually sorts itself out smoothly, without too much additional tweaking needed. With the Morph Target pretty much finished, I moved on. You can see the final result here. [Picture 7]



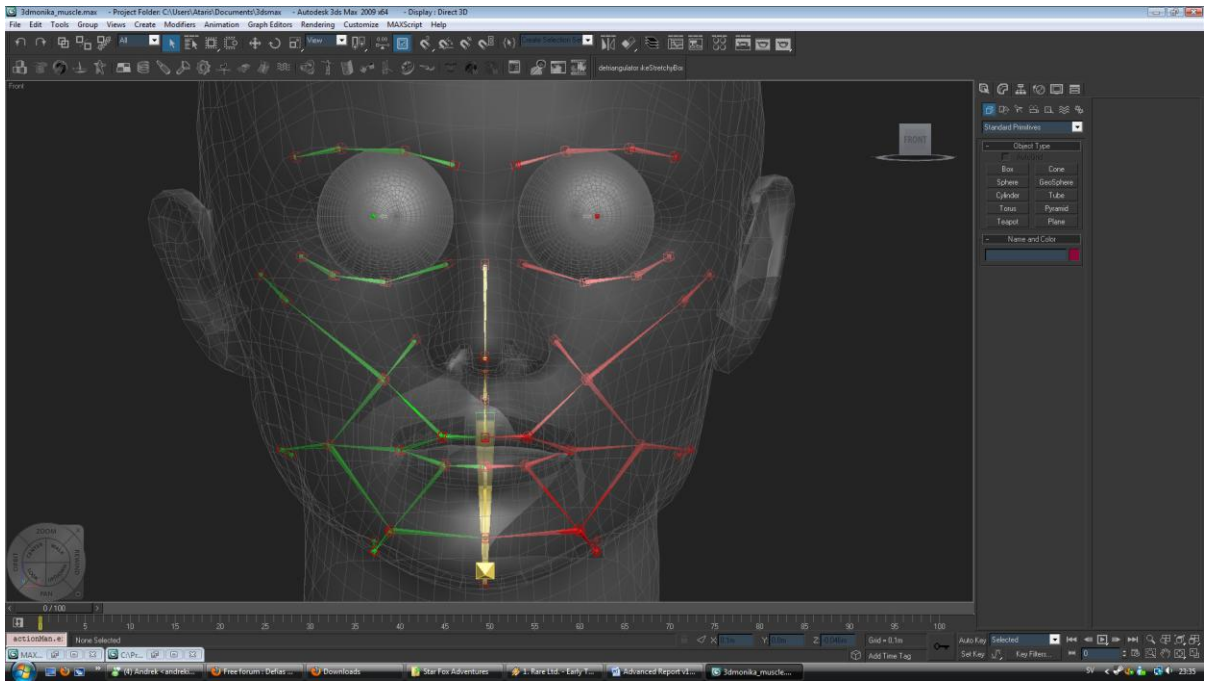
Picture 7.1: Our model, happy that it's all over…



Picture 7.2: …but a bit sad all the same, it's a bittersweet feeling.

Next I started on the muscle-based Skeletal Animation rig. The principle is to use the same kind of system as a regular Skeletal Animation rig. However, instead of setting up a few bones that move different parts of the face, one instead sets up a lot of bones in a pattern similar to the muscles in the actual face. Using "stretchy bones" you can simulate actual muscles using bones, constraints, helpers and some basic scripting. This method is quite performance-heavy, but gives unprecedented detail and flexibility when it comes to facial animation.

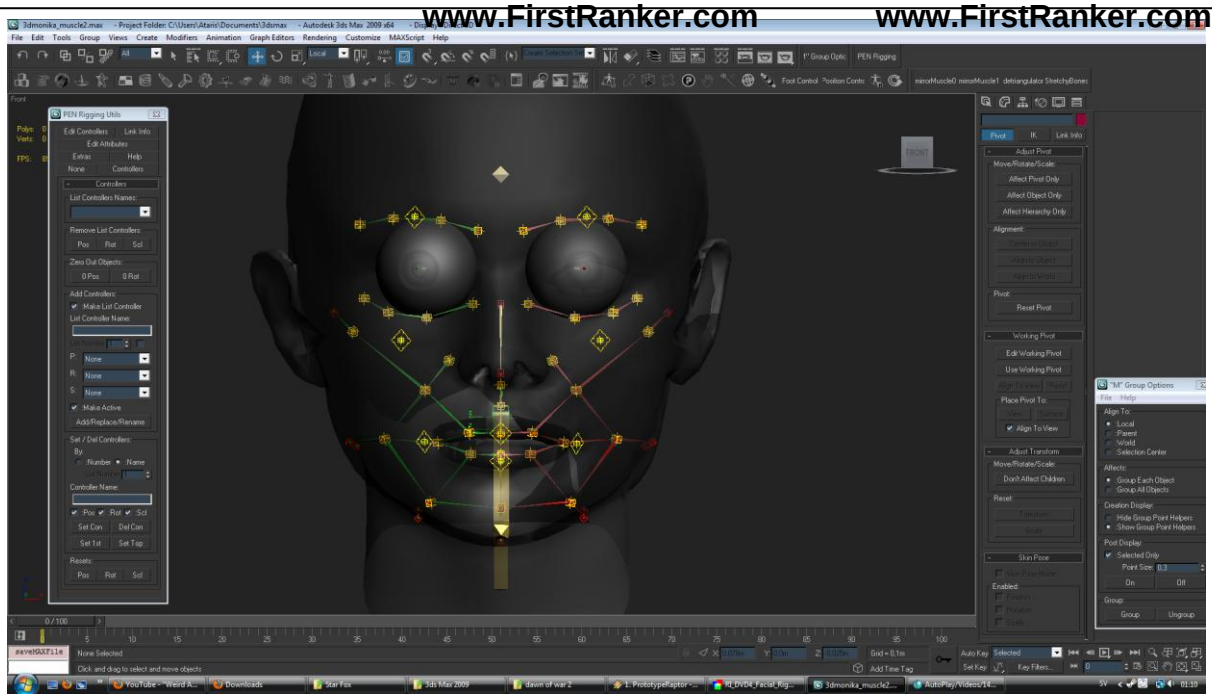
I started with constructing the loops and rings of bones needed to simulate the muscles. What's important is to make sure everything is aligned and mirrored correctly, in order to get good stretching. I then use Point Helpers and constrain them to the bones in order to get the stretchy system I need. This is the result. [Picture 8]



Picture 8.1: The muscle-based skeletal system, with the point helpers attached.

I next added some basic skinning properties to the bones to get started with something. I skinned the jaw bone with a lot of control and parented it to the head. All muscle bones were given moderate influence over the face and the upper half of all muscle bones were parented to the head, while the lower half of the muscle bones were parented down to the jaw.

Next was the extensive process of setting up all the controllers and their values. This is what most of the time will be spent on with the exception of the additional polish at the end. Using parameter wiring and extensive parenting I proceeded to set up the entire facial muscle system. [Picture 9]

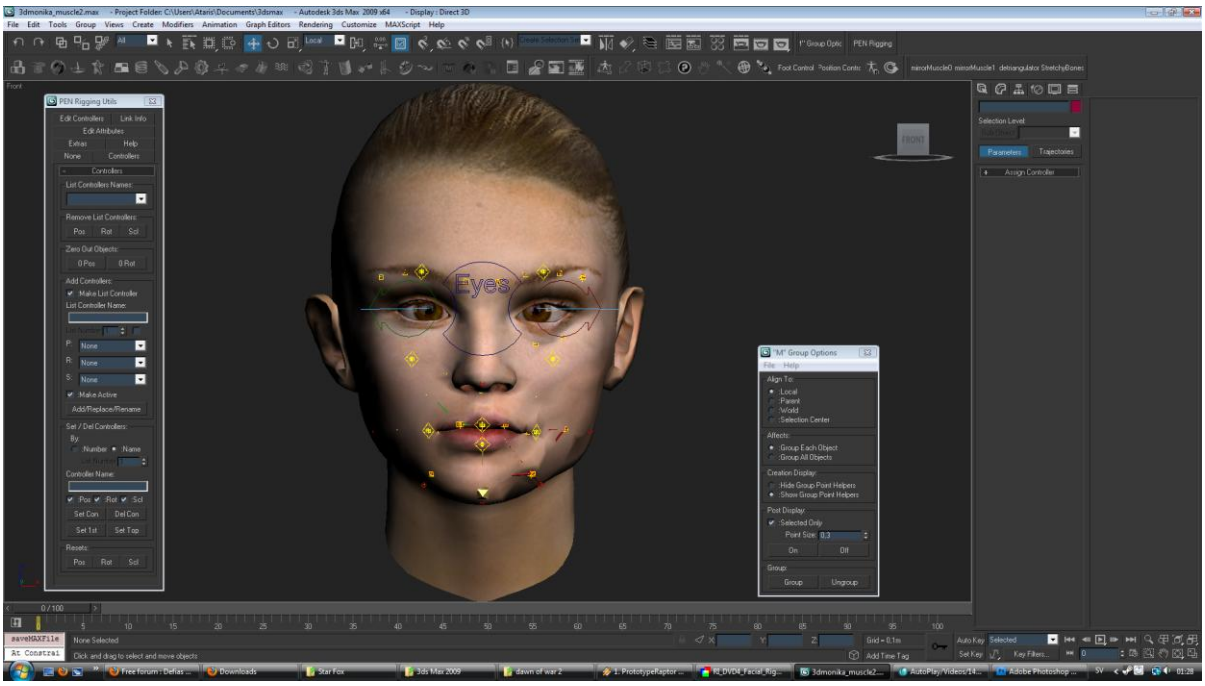


Picture 9.1: The muscle-based skeletal system is now setup with controllers and basic skinning. The result is pretty good for the amount of time spent, but it's in the skinning tuning and fine controls that the real potential for detail is found.

The controllers will affect multiple muscles in the face in order to quickly simulate an actual face. The effect, even at its most basic level, is quite impressive. With some extra work on the skinning and some controllers for fine tuning, it easily becomes the most realistic and expressible setup for facial animation.

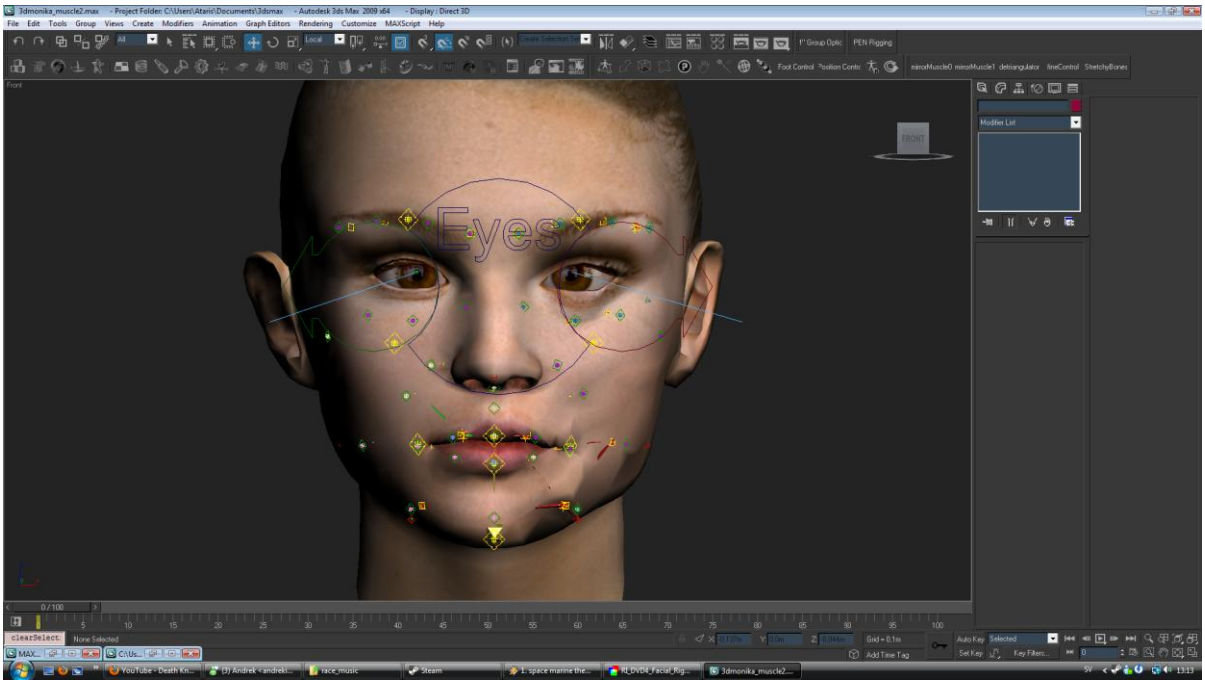
I proceeded to setup the eyes in a basic measure in the same way I did for the Morph Target model. It has the advantages of both being quick to produce and easy to use. The eyebrows are also setup in the same manner as the Morph Target in that the X-axis of the eyebrow controllers also controls how much influence the Y-axis will have on each side of the eyebrow. This can of course be adjusted into multiple controllers, but this setup is a lot quicker to use for the animator since they only have to keep track of one controller. [Picture 10]

The result is already really good, but not fully controllable to the extent needed. To fix this I set up master controllers that control each joint individually. This gives the animator tuning capabilities down to each single muscle and helps a lot when you need to fix certain issues like clipping. It also helps if you ever want to add that extra layer of detail.



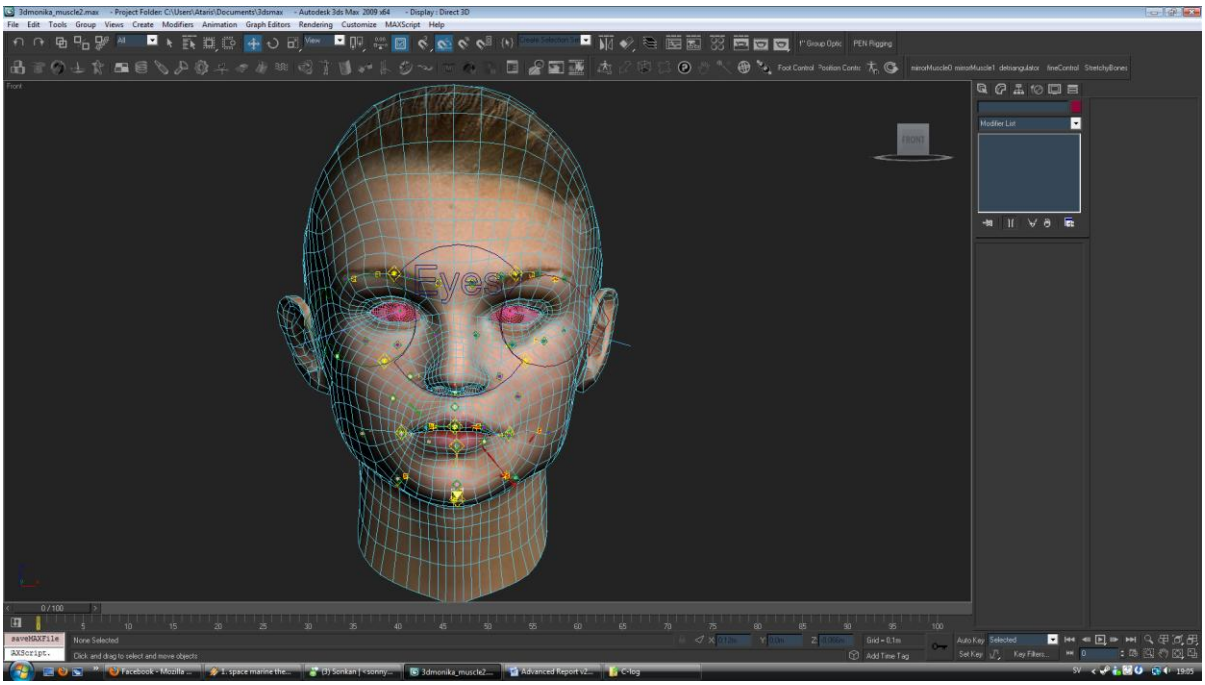
Picture 10.1: The eyes are now setup. This is what the model and control system looks like with the textures displayed.

are the results so far. As you can see the interface might become overwhelming, which is probably the one and only downside of this method. What it does is give very realistic and full control over each muscle. [Picture 11]



Picture 11.1: The master controls are now setup. These controllers allow for extreme fine tuning and adjustment by the animator.

The rest of the work is just fine-tuning on the skinning and parameter weights. You can see the end result of the muscle-based Skeletal Rig here. What is worthy of note here is that I had limited time. This setup could probably be pushed to even further refinements and iterations. [Picture 12]



Picture 12.1: This is the final setup for simulating muscles using bones. All the controls are in place and the skinning has been touched up a bit. It can be pushed even further, but due to a lack of time I cannot take it further as of now.

Conclusion

I think all things considered each way of animating and rigging a face is useful depending on the needs of the production. There are many advantages and disadvantages to each of the different ways of rigging and animation. It all depends on the amount of detail needed, user-friendliness in animation UI, target platform, target medium, specifications of the engine or renderer used and time available. Regular Skeletal Animation is generally the fastest way of animation and rigging. The drawback is that you won't get as much control or detail as the other methods. This makes it ideal for low detail characters and the like.

Regular Skeletal Animation does not drain as much resources as the other methods either (though this depends on the amount of bones that can affect a vertex. 4 bones drains double the amount of resources that skinning a vertex to 2 bones would, provided the entire model follows the same principle). [10]

Some engines can only handle regular Skeletal Animation and as such this is your only method of animation.

In summation, you will want to use regular Skeletal Animation when:

- Your animations need to consume a low amount of resources in-game.
- Your character does not require a lot of details.
- The engine can only handle regular Skeletal Animation.
- Your character needs to be produced quickly.

Morph Target technically gives the most control over facial animations, at the cost of time. This method is preferable if you need a high amount of detail in your characters' faces and your engine supports it. If your engine does support stretchy bones however, you might want to consider Muscle-based Skeletal Animation, at least for your main characters, as that gives the highest amount of detail and control possible out of these three methods.

The advantage that Morph Target animation has over Muscle-based Skeletal Animation however is that it has a very user-friendly interface. There are two different setups, depending on if you want your character to talk a lot or make a lot of expressions. It is possible to combine the two different setups as well, something you might want to consider doing on your main characters in a game. Morph Target is slightly more time-consuming than regular Skeletal Based animation, but it is definitely something to consider if your engine supports it.

Something that should be kept in mind however, is the fact that you need to know beforehand what facial expressions the character needs to be able to make, due to the fact that they all have to be modeled individually. It can be troublesome to find out your character is missing one or two Morph Targets that it needs to make a certain expression and go through the trouble of adding those, followed by going through the entire pipeline again to make sure everything works.

In summation, you'll want to use Morph Target animation when

- Your character needs a high amount of detail in its animations; say a main character or the pre-rendered CG.
- You need a user friendly interface for animation.
- Your character needs to be produced in a moderate amount of time.
- Your engine supports it or you're producing a pre-rendered cinematic or cutscene.
- You know all the animations your character needs when you start rigging.

Muscle-based Skeletal Animation is a pretty new thing in animation, at least in the video game industry. To make it work the engine has to support stretchy bones, which is pretty rare so far. However, for the time spent on the model you will get unprecedented control and detail in your animations. It takes longer to set up a basic version of this than the others, but once you're there you can do a lot of crazy movements with your model's face without having too many issues. I personally think this is the method to go with if your engine, team and end-user can support it. That said, it still takes some time to set up properly and not all animators might be used to

the interface. The only real drawback is that this method is quite performance-heavy, and thus might not be desirable when it comes to all video games.

That said this is by far the highest quality you'll get weighted against the time you spend. I think it is possible to go above and beyond with Morph Targets, but then we're talking ridiculous amounts of time, something you generally cannot afford in a normal production.

In summation, you'll want to use Muscle-based Skeletal Animation when

- Your character needs an extreme amount of detail and flexibility in its animations; examples include main characters, next-gen characters and pre-rendered animations.
- The engine actually supports it by stretching bones.
- Your character needs to be produced in a moderate time, or if time is plenty.
- User performance isn't an issue.

I draw these conclusions from my own personal experiences and testing, research and other technical animators' thoughts on the matters. While this does not make the results and conclusions one-hundred percent factual, I think it does at least warrant consideration in any future projects, like much with the games industry.

As for me personally I feel that overall, the project was a success. I started off with little to no experience or knowledge surrounding the skinning and animation of faces in the video game industry. I proceeded to learn the basics and moved on to actual practice. I learned a lot on the way, even what I would claim are some of the more advanced matters within the subject. I know exactly what I would use if I was able to and when. I had a lot of troubles on the way however, and were it not for the plan I had set up I'm not sure I would've been as aware of the time left as I was. The backup week also helped a lot since I would otherwise have been short some 3 days on the Morph Target animations and would not have had any time at all to research and work with the muscle based Skeletal Animation.

In conclusion, I am glad that I went through with this project and I am very happy with the results.

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Appendices

This is the 3D head using a basic Skeletal Rig -

This is the 3D head using Morph Target animations -

This is the 3D head using a Skeletal Rig to simulate muscles -