Graduation Report:
ANATOMY OF A HUMAN HEAD

A report covering the creation process of an anatomical model of the neck and head area of a male human.

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Abstract

In this paper the creation process of an anatomical model will be discussed. The product can be used to create anatomical illustrations or it can be viewed in Maya. Due to the proper naming and hierarchy of the different objects, it will be easy to isolate the area of interest. Since the model will also be used for rendering; shaders, UVs and a lighting set-up are also part of this project and thus will be discussed in this paper.

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1. **Introduction**

The graduation project is about the creation of an anatomical model. The main focus during this project is to create a model that is anatomically accurate. But at the same time it also needs to be viewable in real-time and the user needs to be able to interact with the model to isolate the area of interest. On top of that the model also needs to be used for high resolution rendering. Finding a balance between these three factors is a challenge.

The graduation period will build upon my work done during the specialization stage. During the specialization stage the bones of the skull, spine and arm were created. These bones are the foundation of this project. All of the muscles, ligaments and all the other anatomical objects that are present in the head and neck are build based on these bones.

This project will combine all of the skills and knowledge I've acquired during my education at the NHTV. It will include modeling (NURBS and polygonal), sculpting, UVing, texturing, shader writing, lighting and rendering.

A medical background is a pre when it comes to viewing and understanding this model. But even for people without a medical background, it will be an interesting experience to discover all the little bits and pieces that make up the human body. To better help understanding the complexity of this model I will not only discuss the technical part of creating the model, but also a little bit of the research I carried out about the function, shape and position of the different anatomical objects.

1.1 Important

Maya 2012 should be used for viewing. If the textures are not loading it is because the project is not set to the right folder. The project needs to be set to the "rJoosten-Graduation" folder.

2. Setting the standard

It is important to create a standard for the model. Setting a standard early makes it easier to maintain a consistent look. The look doesn't only refer to the textures, shaders and normal maps but also about the overall resolution of the model.

2.1 Resolution

The resolution has already been discussed during the specialization stage. During this stage I've already took into account the possibility of expanding the anatomy project with more than just the bones. This project also doesn't cover the entire human body but just the head and neck area. Making an estimate of what the polycount of a complete human model would be is impossible. Therefore it would be useless to focus on reaching a certain number of triangles. Instead the focus will lie on keeping the polycount as low as possible without losing too much detail.

Fig. 01: Silhouette View

During the specialization project two types of resolutions were created. One for medium close-up renderings and one for extreme close-up renderings. Due to the workload it is only feasible to create a model once with one resolution . Because only one model of every subject will be created, it immediately should be suitable for extreme close-up renderings.

Based on this information a square face should be somewhere between 0.25 and 0.50cm2. This not an absolute rule. Based on the curvature of the model the resolution can either be increased or decreased. An easy way to test if the resolution is high enough is by looking at the model in silhouette.

2.2 Look

The look is another important subject that needs to be addressed beforehand in order to maintain an overall consistency throughout the model. There are a couple of things that have to be taken into account. Based on time and performance constraints yet still maintaining an esthetically pleasing look, a decision has to be made.

If a realistic look is to be achieved, every single muscle needs to be sculpted. There are 220 muscles in the face and neck. This means that for the muscles alone 220 different maps need to be created. This doesn't even include the ligaments, brain and all the other stuff that is present in this model. So a realistic look is not achievable both due to time and performance constraints.
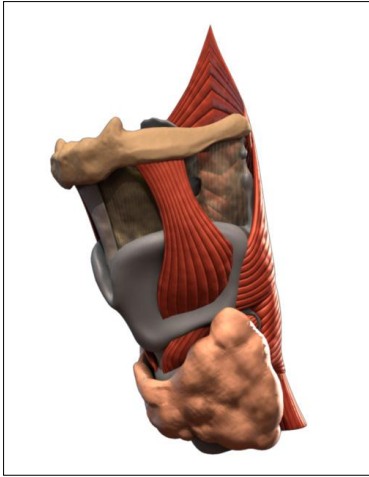
Another option is go for a stylized look without textures and separate the different subjects based on color. Performance and time wise this would be a great solution, but the lack of additional detail really puts down the esthetically pleasing look of the model.

This means that a fine balance between a realistic look and a stylized look is the best solution. This includes sculpting the more prominent subjects like the brain and cartilage to add additional detail to the low resolution mesh by means of a normal map. But at the same time only using color information to distinguish different objects within the model. The color information is not realistic but makes it a lot easier to understand the model.

Fig. 02: Stylized look example

2.3 Map size

The resolution of the maps need to be based on the size of the surface. It is important that a pixel will be roughly the same size all throughout the model. The following image is taken from my specialization report.

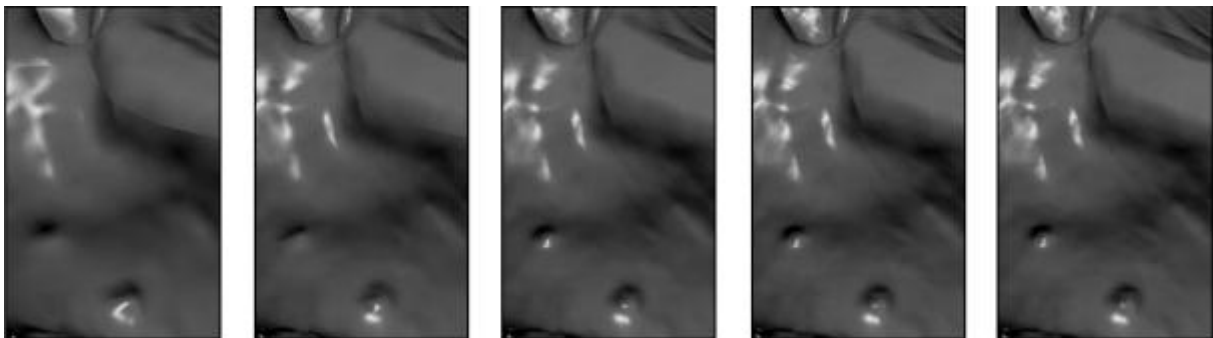

Fig. 03:   128x128   256x256   512x512   1024x1024   2048x2048

The 128px and 256px clearly don't suffice and are lacking a lot of detail. The difference between the 512px and 1024px is still noticeable were the 512px images is still lacking some detail. The difference between 1024px and 2048px hard to notice, therefore the 1024px is the best choice. This means that 1024 pixels should cover around 12 centimeters in real life.

3. Skull

The skull is one of the objects that was already created during the specialization stage. After doing more research about the inner ear and paranasal sinuses, it became obvious that the skull earlier created still had some errors present in the model and of course the missing information in the form of the inner ear and the paranasal sinuses needs to be added.

3.1 Revision

The sutures were the biggest area of interest. They were incorrect in many places and had to be fixed. Using the soft selection tool or the wire tool to manipulate vertices in a better position. Below is an example of the suture that was the most troublesome , which was the sphenosquamosal suture. Instead of a suture there was just a big gap as can be seen in the image below.
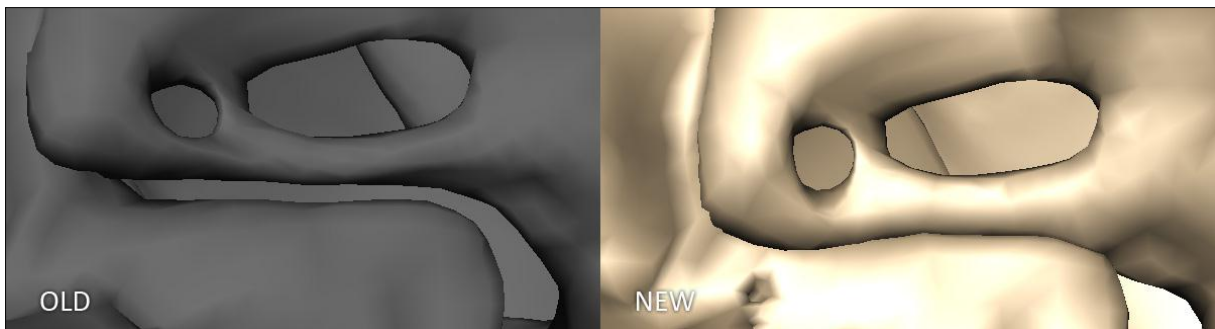

Fig. 04: Suture fix

The other problem was not present in the geometry but in the normal maps. Although it was thoroughly checked there were still some issues mainly in the foramen and texture seams, these problems were fixed by painting over the problem areas in Photoshop. Because the errors were really small and hard to notice it was not worth re-projecting the maps.

3.2 Adding information

After fixing the already present issues it was time to finish the skull and add the last pieces of missing information. The paranasal sinuses, the inner ear and three of the bigger foramina still need to be added. After adding these elements there are still some smaller foramina missing. The normal map will point out there is a foramen there but the canal won't be build.

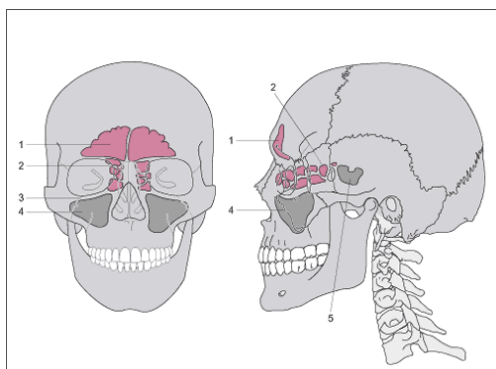### 3.2.1 Paranasal sinuses

Fig. 05: Paranasal sinuses [1]

The image on the side shows the paranasal sinuses of the human body. Only the ones in the maxillae (1) were present in the original model. This means that the sinuses of the sphenoid (2), ethmoid (3) en frontal (4) bone still need to be added. Since all of the sinuses have a more or less circular shape, smoothing a cube and manipulating it into shape does the trick. Accept for the sinus in the frontal bone, that one took a little bit more work and preparation to get the desired result.
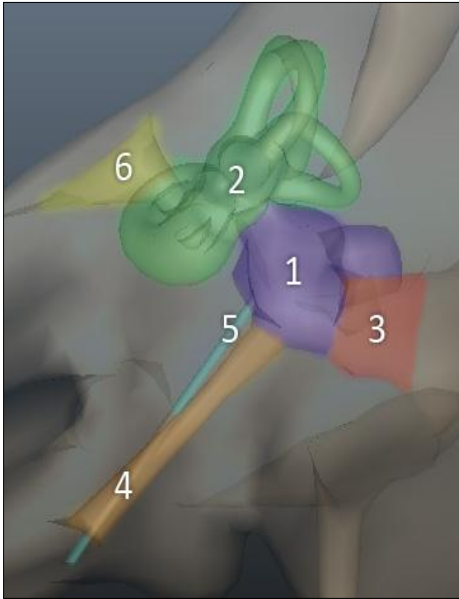
3.2.2 Inner Ear

Fig. 06: Temporal cavity

The inner ear is one of the smaller pieces of this project. There are a lot of little pieces that make up the inner ear. But I started off by carving the tympanic cavity (1), cochlea (2), external auditory canal (3), Eustachian tube (4), the foramen of the tensor tympani (5) and the foramen for the vestibulariscochlearis nerve (6) out of the temporal bone.

I misinterpreted the reference and made a mistake by creating the Eustachian tube where the carotid canal should be. I only discovered this problem when I was working on the cartilage of the auditory tube. I've created the cavity with simple patch modeling. Another problem with adding this cavity to the temporal bone was the fact that the UV space was already filled, therefore I had to create a different shader to assign to the cavity.

The ossicles consist of 3 small bones named the stapes (3), incus (2) and malleus (1). The bones have a complex shape and if the resolution rule is to be followed it would lack a lot of definition, therefore a resolution of a square face every 0.1cm2 is a better option for these small parts. Another important part is the connection with the bony labyrinth (4) which holds the vestibular system. The bony labyrinth has an really complex shape but the Sobotta books have excellent orthographic views which make it a lot easier to understand the complex shape of the model and convert it into 3D.
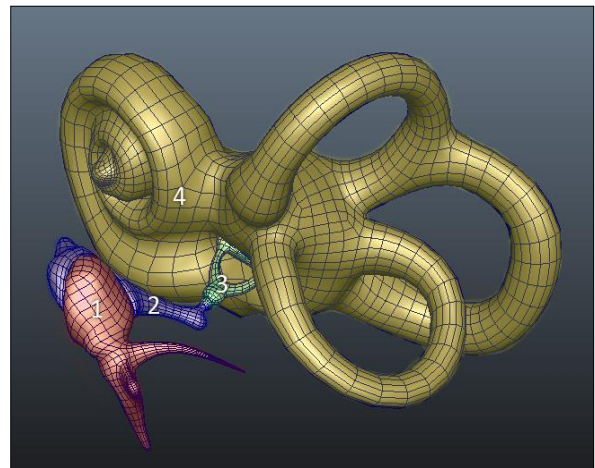

Fig. 07: Ossicles & bony labyrinth

4. Muscles

There are 220 muscle in human neck and head. The creation process of all these muscles will be the same, therefore I won't go over all of the individual muscles. Instead I will focus on one muscle and point out the area of interests. This process isn't limited to just the muscles, but it also applies to the ligaments and the membranes.
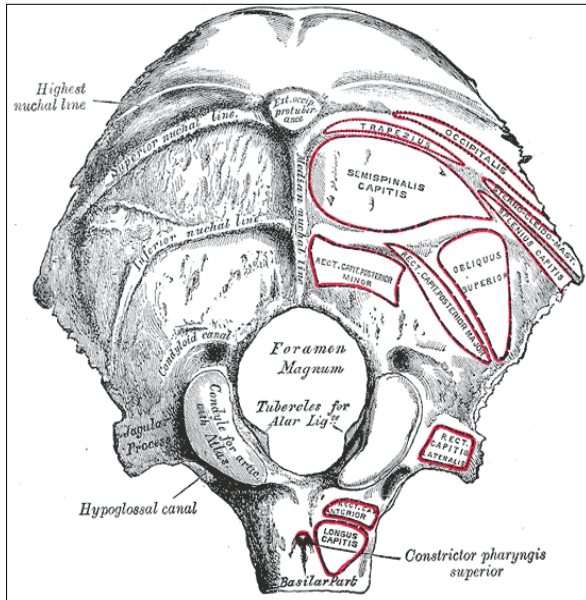
4.1 Creation process

Fig. 08: Insertion Example [2]

NURBS will be used to model the muscles and ligaments, this makes it a lot easier to manipulate the mesh into the correct shape without having to deal with multiple thousands triangles. Another beneficial part of using NURBS is that it already creates the UVs upon converting to polygons.

First it is very important to research the muscle or ligament that has to be created. Gray's anatomy is an excellent book that shows the shape of the insertion and origin of a muscle. Knowing this is already half the work, since muscles usually go straight from the origin to the insertion or fold around other muscles or bones.

The key is to recreate the shape of the insertion and origin with a curve (1) as can be seen in the image on the side. After this a simple loft operation will create the NURBS surface (2). Then adding isoparms and manipulating them into the correct shape of the relative muscle (3). Setting the tessellation settings to match the overall resolution (4). Quadrangulate the mesh and make minor adjustments (5).
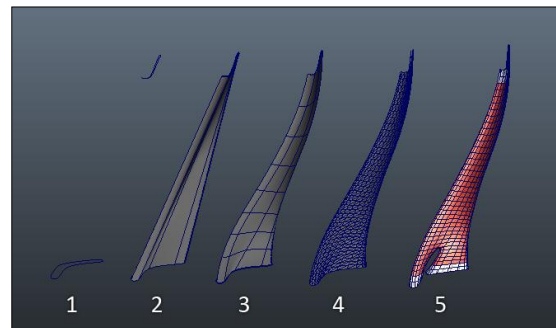

Fig. 09: Muscle Creation Process – One

Another possibility is to extrude a profile curve along the length of the muscle (1). This will create the NURBS surface (2). The following steps are exactly the same as the ones earlier described. Based on the shape of the muscle one method works better than the other. For straight muscles (Zygomaticus Major) use the first method and for odd shaped muscles (Sternohyoideus) use the second method.
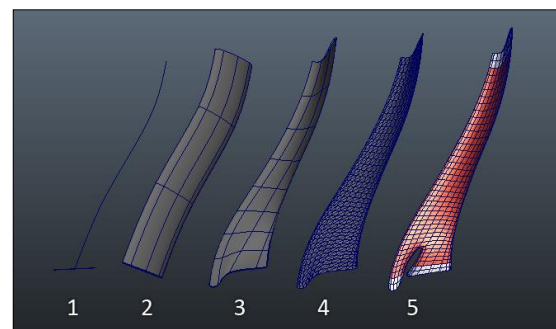

Fig. 10: Muscle Creation Process – Two

Then there are still two muscle that don't fit one of the two categories, this is the Orbicularis Oculi and the Orbicularis Orbis. As the name of these muscle already points out; they are torus shaped muscles. Since there are only two of them the best idea is to spend the extra time and manipulate a NURBS torus in the shape of the relative muscle. Once the NURBS surface has the right shape step 4 and 5 can also be applied to this model.

4.1.1 Mirroring

This might seem like one of the easiest tasks, but this is not the case. The skull is non-symmetrical. This means that a muscle might fit on the right side but it won't fit on the left. The changes that have to be made are very small. But it is never easy to manipulate a multi thousand triangle object with the soft selection tool, this will immediately ruin the smooth meshes created from the NURBS surfaces. This means that the use of a deformer is a better option to manipulate the mirrored mesh into shape.

If really small changes have to be made the Wire tool might suffice. The big drawback of the Wire tool is the fact that it only rotates the mesh based on the tangency of the curve. For a more precise approach both the NURBS surface and the quadrangulated mesh have to be mirrored. Then the polygonal surface can be wrapped on the NURBS surface with a Wrap deformer. The result being that all of the changes made to the NURBS surface will also change the polygonal mesh.
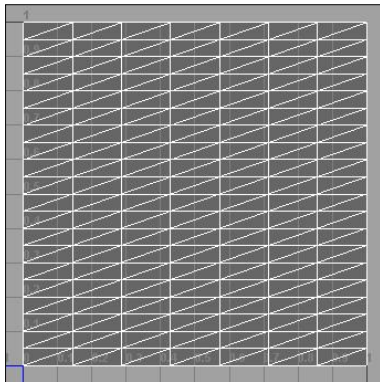
4.2 UVs

Fig. 11: Raw UVs

As earlier mentioned in this chapter the UVs are automatically created by converting a NURBS surface into a polygonal mesh. The only problem is that it fills the entire 0-1 UV space, as can be seen in the image on the side.

The UVs then need to be manipulated to match the shape of the muscle. Another problem is that the UVs are laid out evenly while on the mesh the edge rows might not be evenly spaced. Assigning the shader that will later be discussed in this chapter will help in adjusting the UVs by hand to get the desired result.
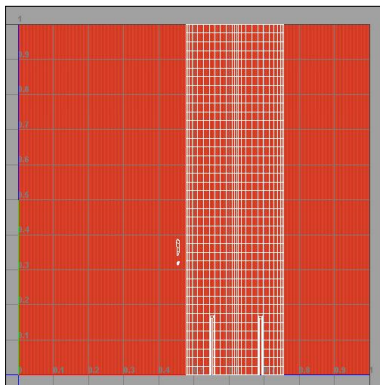

Fig. 12: Final UVs

Figure 12 is an example of what the end result might look like. The edge rows are adjusted to create and evenly spaced pattern on the mesh. The caps that are created for some of the muscles are projected separately.

To create an more interesting look it is possible to vary the width of the fibers throughout the model. This can be done by varying the UV space between the difference edge rows a little bit.

4.3 Shader

The shader is the most important part of the muscle, ligament and membrane objects. Since these three types of objects are present all over model it is important to make it look interesting without creating a different shader for every single muscle.

These are the critera for the shader:
1. Low resolution maps (for real-time viewing)
2. Tileable textures (to represent the muscle fibers)
3. Additional bump information based in 3D space (this will prevent a boring look)
4. Four different shaders. (Muscle, Muscle Tendon, Ligament, Membrane)
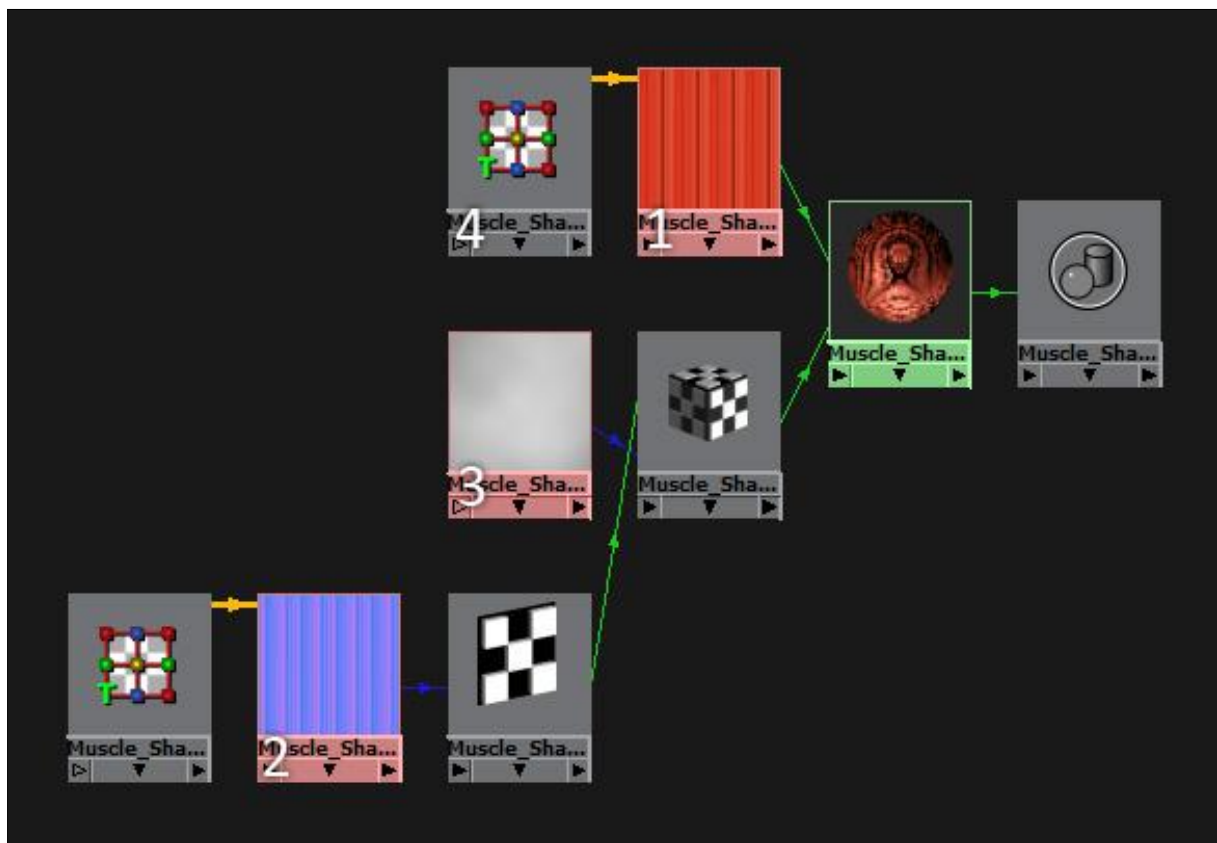
Fig. 13: Shader Network

The image above shows the shader network of the muscle shader. The diffuse and normal maps are only 64x64 pixels (1,2). This is then tiled a 100 times by the texture placement node (4). The nifty part of this shader is the additional bump information added by a 3D texture (3). The normal information from the 2D bump map node is connected with the normalCamera attribute of the 3D bump map node. This adds both the normal map information with the random 3D bump to create an interesting and non-uniform look.

The other three shaders use the same node network accept for some minor changes to the parameters. For example the tendon shader gets a different diffuse map. The ligament shader gets a different normal and diffuse map and transparency is added to the membrane shader.

5. Cartilage

There is a lot of cartilage present in the human head. In general the cartilage is there to give the overlaying structure some strength and flexibility as can be seen in the Nose (3) and Ear (4). In some cases it also allows for small movement of the bones or muscles it connects to as can be seen in the Vertebrae (2) and Eustachian tube (5). Then there is still the Larynx which is the most complex of the cartilage in the head and gives the throat strength. Muscles connect to some parts of the cartilage too control the vocal cords (1).
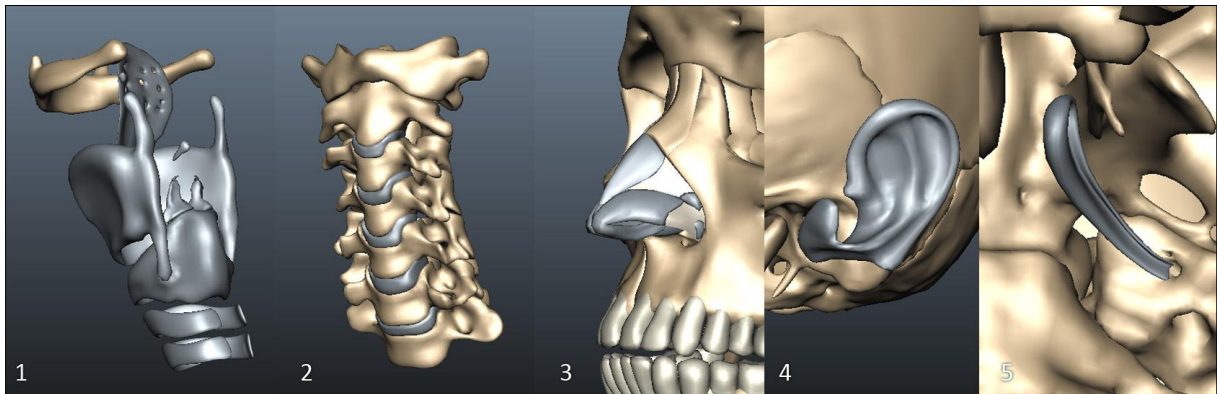
Fig. 14: Cartilage examples

5.1 Creation process
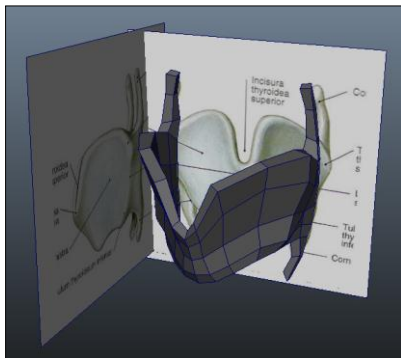
Building these objects starts with great reference. Sobotta has excellent reference with orthographic views, these views they can be set-up in Maya as can be seen in figure 15. This gives a better understanding of what the model looks like in 3D. Patch modeling is the best method to get the rough shape of the object. In this stage maintaining the set resolution is not important, it is best to roughly use half of that. By using a lower resolution the modeling process is a lot faster. The detail is added later on by sculpting the low resolution mesh.

Fig. 15: Low resolution mesh

5.2 Sculpting

The low resolution mesh earlier created will be imported in Mudbox. The mesh can be smoothed and then sculpted with the tools available in Mudbox. Using the bulge, move and smooth tool I manipulated the smoothed mesh into the desired shape. Since there cartilage is smooth there is no use for custom brushes and stencils. An example of the end result can be seen in figure 16. Both the highest subdivision and first subdivision level can be exported for normal map projection. But only first the first subdivision level needs to be UVed.
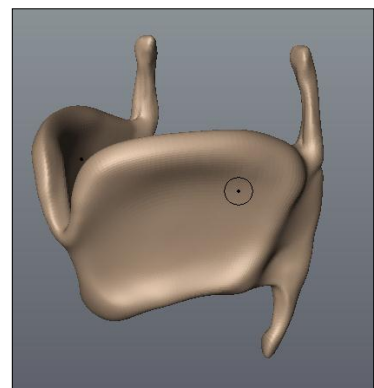

Fig. 16: Sculpted mesh

5.3 UVs

Maya is a great program for UV projection and unfolding but when it comes to really complex shapes, Maya some time doesn't give the desired result when it comes to unfolding the UVs. Roadkill is a better program for UV unfolding. The problem is that Maya also takes the 3D space of the object into account when it unfolds UVs, with complex shapes this causes overlapping UVs. Roadkill doesn't have this issue and is therefore a better option.
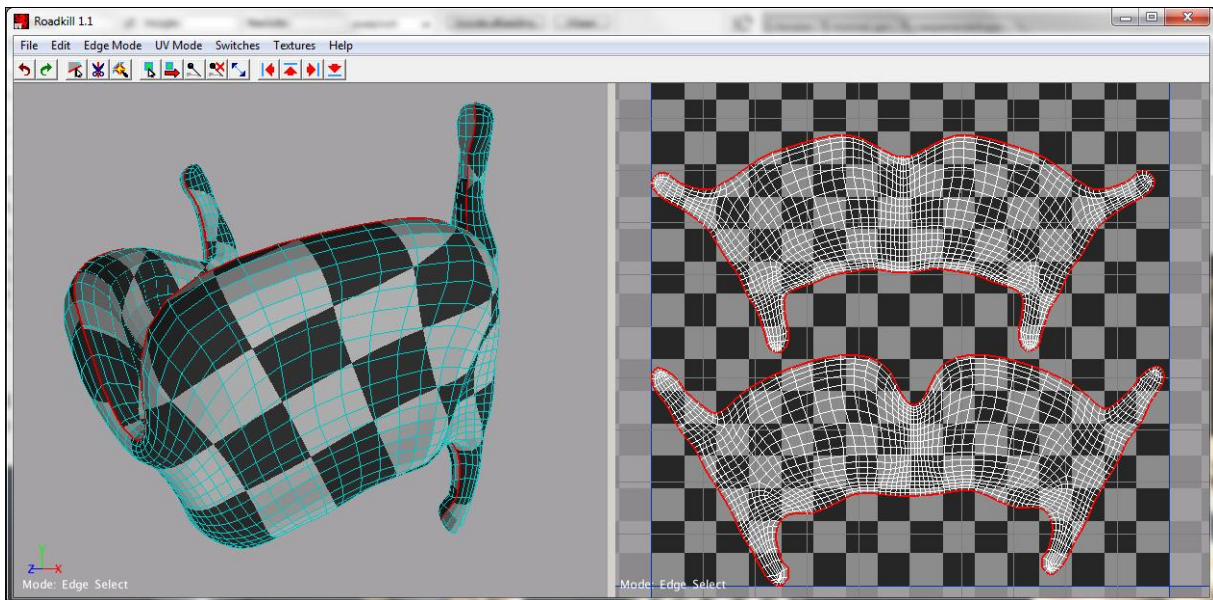

Fig. 17: Roadkill example

5.4 Normal map projection

The best program for normal projection is xNormal. It gives the best results and the user input is limited to a couple of settings which are easy to understand. The low and high resolution mesh need to be imported. After this the search distance, edge padding and map resolution can be set. These are the only parameters that will change the output of the image. So if there are problems with the normal maps it can be fixed by changing the search distance and edge padding parameters. The following image is taken from my specialization report.
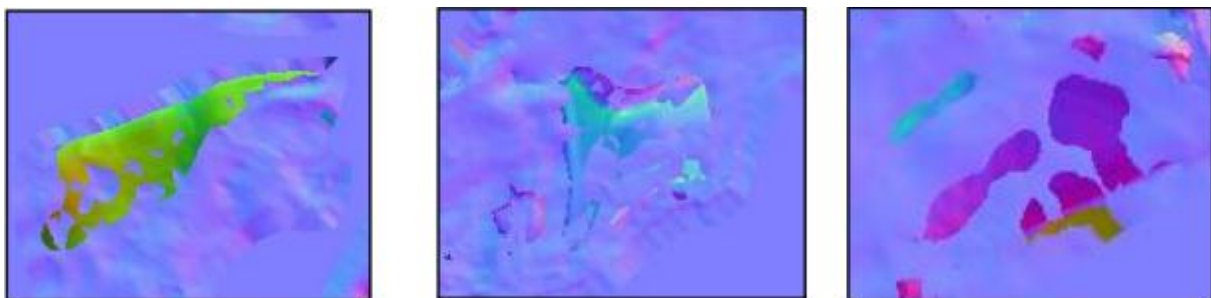

Fig. 18: Normal map errors

In some cases the geometry is so complex it is impossible to get a problem free normal map. Fixing these issues in Photoshop is the only option. The smudge and stamp tool is the best way of getting rid of the smaller errors.

6. Brain

The brain is the most complex model of this project. To get a better understanding of the 3D shape of the brain I've bought a real life model. I've asked my fellow student Nick Peters to scan the model with his 3D scanner. Unfortunately the model doesn't cover all the different bits and pieces of the brain. This means that the scanned data can only be used as a reference. But working with 3D reference is easier than creating something this complex from nothing but images. The first step is too retopologize the scanned data.

Fig. 19: Scanned mesh

6.1 Retopologizing
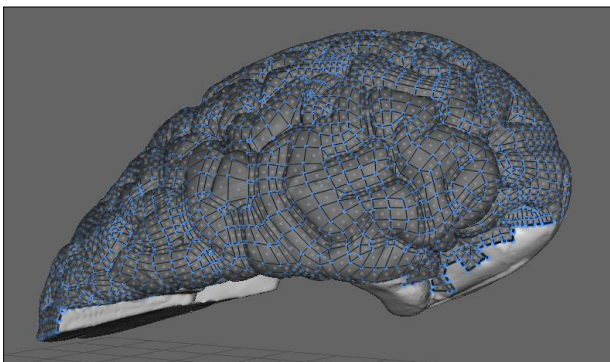
Fig. 20: Topogun example

Before the retopologizing process can start the scanned data needs to be positioned correctly to create a fully assembled brain. The program used for the retopologizing process is Topogun. It is designed in a way that you can paint a new topology on top of a high resolution source. This process is nothing more than placing and connecting points to create a closed mesh with an interesting and effective edge pattern.

Since the model comes apart some of the meshes need to connect together, this is something that has to be taken into account. The key is to roughly place the vertices at the same position of the connection area of the two surfaces. Topogun can't import two high resolution meshes at the same time, therefore the placing of the points have to be carefully planned at the connection area of the two surfaces. As can be seen in figure 21.

Fig. 21: Combining meshes

6.2 Adding missing data

The model that was used for scanning is very detailed but it combines a lot of information into one surface. The key is to recognize these elements and carve them out of the original mesh. Most of these elements can be found in the brain stem, this will be discussed in further detail. The olfactory tract (1) and corpus callosum (2) should be separated from the cerebrum (fig 22). The two scanned parts of the cerebellum should be fused together.
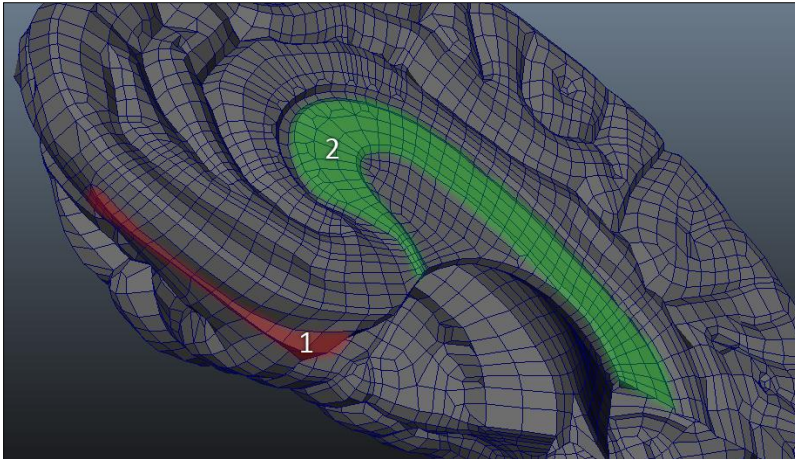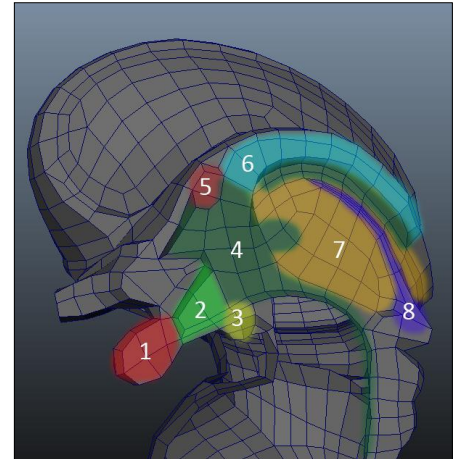
Fig. 22: Cerebrum

Fig. 23: Brainstem

Figure 23 shows some of the different elements which are fused together in the original model. hypophysis (1), hypothalamus (2), limbic system: corpus mamilliare (3), fornix commissure (6), ventricle system (4), anterior commissure (5), thalamus (7) and the pineal gland (8). From these different elements the thalamus, hypothalamus, limbic system and ventricle system are complex and interesting enough to be discussed separately. Added to this list will be the basal ganglia, it is not visible in the images, because it is embedded deeper inside the brainstem.

6.2.1 Thalamus
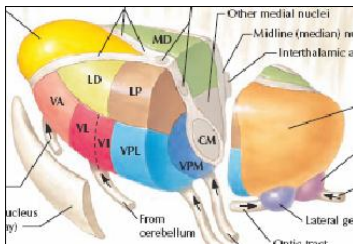
Fig. 24: Thalamus

The thalamus can be seen as a switchboard of information, this means that it is one of the most important parts of the human brain. The thalamus as a whole is oval shaped, at a first glance this might seem like an easy modeling job. But it consists of different nuclei as can be seen in figure 24. Creating all these nuclei and maintaining the right shape is quite a challenge.

The way I tackled this problem is to use a polygon sphere and manipulate it into the correct shape. After this I created an edge pattern on top to outline all of the nuclei (fig 25). I've then separated all of these outer surfaces of the different nuclei. After this the inner surfaces could be created (fig 26). This creates an perfect fitting and solid thalamus, which can be rendered as one piece.
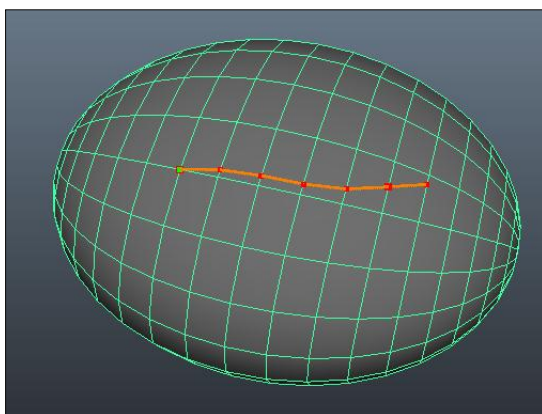

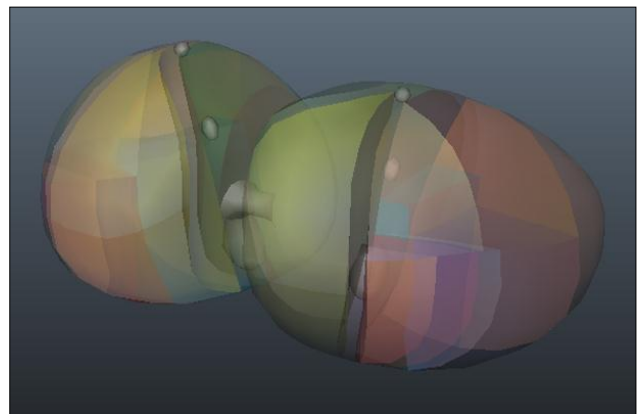Fig. 25: Thalamus (Outer Surface)
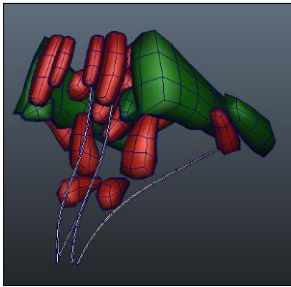

Fig. 26: Thalamus (X-Ray view)

6.2.2 Hypothalamus

The hypothalamus are a bunch of nuclei that control emotions, body temperature heart rate etc. It also connects with the thalamus and the hypophysis. The modeling aspect of this part of the brain is fairly easy, but it has proven quite the challenge to get all of these nuclei in the correct shape and fit within the already created part of the brain. If this particular part is looked at in greater detail it really shows that every nuclei has its particular shape and fits in perfectly with the rest.

Fig. 27: Hypothalamus

6.2.3 Limbic system & Basal ganglia

This part is hardly visible in the scanned model. This means that it almost had to be entirely created from 2D reference. The corpus mamilliare and fornix commissure are the only thing that are visible in the scanned model of the brain stem. The corpus amygdaloideum and hippocampi can be found in the scanned model of the cerebrum. Already having located these areas make it easier to connect them with each other and maintain the correct shape.
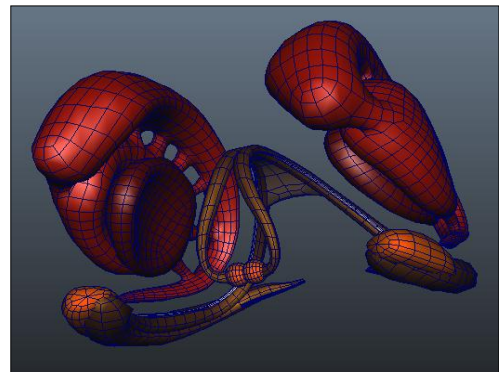

Fig. 28: Limbic System and Basal ganglia
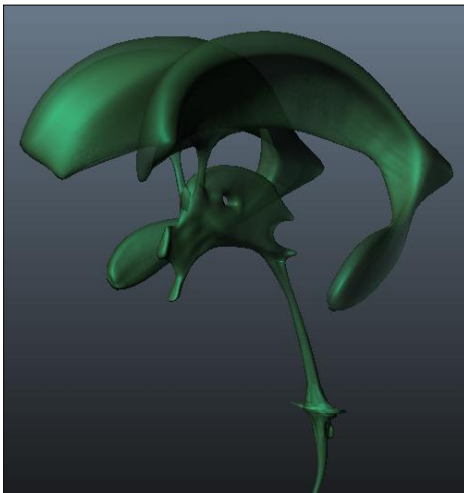
6.2.4 Ventricle system

The ventricle system consists of four ventricles. The first two are the big circular shaped ones that are folding around the basal ganglia. These ventricles are made by manipulating a NURBS surface roughly in the right shape and then edit the converted surface into the correct shape. The third ventricle is the one in the center, it is surrounded by a thalamus and hypothalamus on either side. First I've created the outline with the create polygon tool. After this extruding the patch and manipulating it into shape by creating additional edge loops. The fourth one is connected with the cerebellum. All of these different elements are connected with each other.

Fig. 29: Ventricle system

The modeling is not the most interesting part of this element. The model has to look like it is made from one piece, but as already has been mentioned it consist of multiple objects. Since the model will be cut up it doesn't get the normal information from the adjacent mesh to create a smooth transition (fig 30).

Fig. 30: Normal Error   Fig. 31: Normal Fix

Figure 31 shows what the end result should be like. This is accomplished by transferring the normal information from one mesh to another. This is done by combining all of the objects and merge their vertices in order to create smooth normals. This mesh is then used to transfer the normal information from. This can be done with the transfer attribute tool.

This technique will be used all throughout the project. Especially in the nervous system and in select parts of the brain.

6.3 Sculpting

At the start of the project all of the sculpting in this project was done in Mudbox 1.0. But when de brain came along it became obvious that the limited tools in Mudbox 1.0 didn't suffice in order to get the desired result. Therefore I updated to Mudbox 2012 which has more tools that could aid in giving the brain that extra bit of detail.

Of the brain only the cerebellum, cerebrum, brainstem, insula, ventricle system and limbic system had to be sculpted. Of these objects only the cerebellum and cerebrum will be discussed. The techniques used with these two objects will also apply to the brainstem, insula, ventricle system and limbic system.
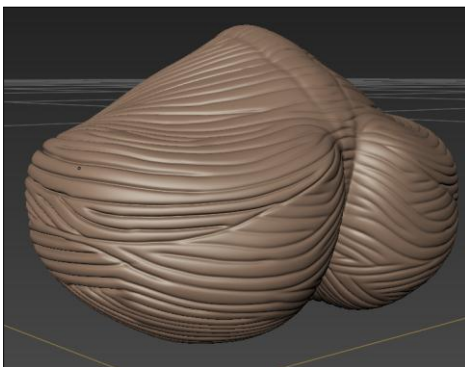
6.3.1 Cerebellum

Fig. 32: Groove pattern.

The cerebellum features a lot of grooves all over its surface. While I was sculpting the cerebellum I discovered that the Mudbox 1.0 tools were not sufficient enough to create the result I wanted. With only the bulge, sculpt and move tool and the lack of a steady stroke function it was impossible to create the nice and clean grooves. The first step is to create the groove pattern in the surface (fig 32). The knife tool is the best option for this process. Like the name already gives away it creates knife like incisions in the surface.

With the groove pattern in place it already creates an interesting look, but it still doesn't look like a cerebellum. This is achieved with the bulge tool. This tool pushes out the mesh based on its own normal. This means that the gaps created with the knife tool will be pushed closer together and the end result will be a clean groove (fig 33).
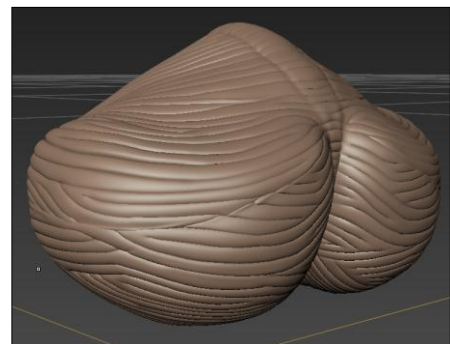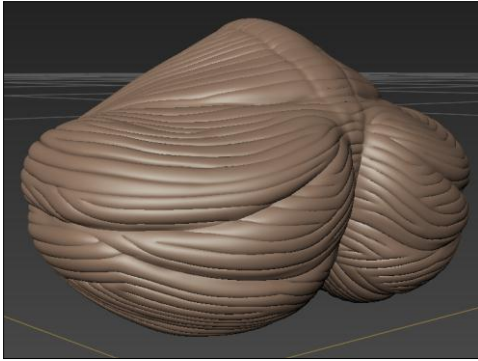

Fig. 33: Clean grooves

16

Fig. 34: Final result
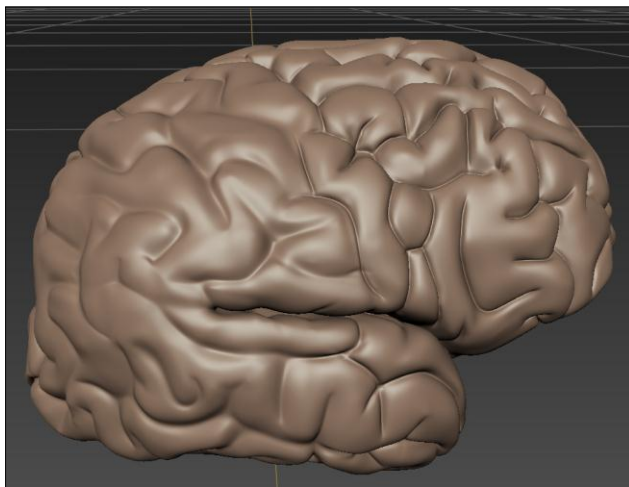
6.3.2 Cerebrum

Fig. 35: Accentuate grooves

When looking at the grooves in extreme close-up it does look the way it should. But overall the cerebellum still looks very dull and uniform. This is fixed by accentuating the different parts of the cerebellum (fig 34).

During the retopologizing process the grooves and dents were already outlined in the low resolution mesh. Where in the cerebellum the groove pattern had to be painted on the surface, the cerebrum already has all these areas outlined and they just need to be accentuated. Due to time limitations I wasn't able to completely create the inner structure of the cerebrum. This means that the underlying structure had to be faked with a sharp indent. This can be achieved using the knife tool with a high strength setting (fig 35).

In order to create the illusion of an inner structure these grooves have to be pushed together with the bulge tool. This will create a clean sharp edge between the different bumps (fig 36). The cerebrum is also a very large surface. Extra bump information can be added to the surface to create a more appealing look. It has to be very subtle since in real life the brain is fairly smooth. The additional bump information can be added with a stamp of a stencil. Adjusting the layer strength will make sure the end result stays very subtle (fig 37).
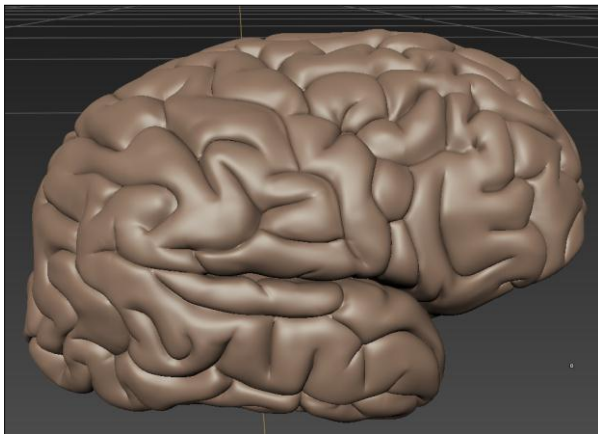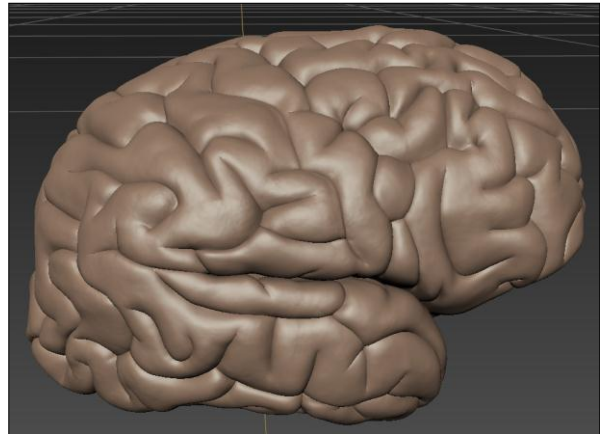

Fig. 36: Bulge Tool

Fig. 37: Additional Bump

6.4 Shaders

Most of the shaders created for the brain only differ in diffuse color, transparency, specularity and reflectivity parameters. These shaders are not worth discussing, but the shader created for the ventricle system, corpus and the nuclei have an more interesting shader network. The technique used for these three shaders are the same, the only difference is the parameters of the ramp shader and if it gets connected to either the transparency or incandescence. Therefore I will only discuss the ventricle system shader.
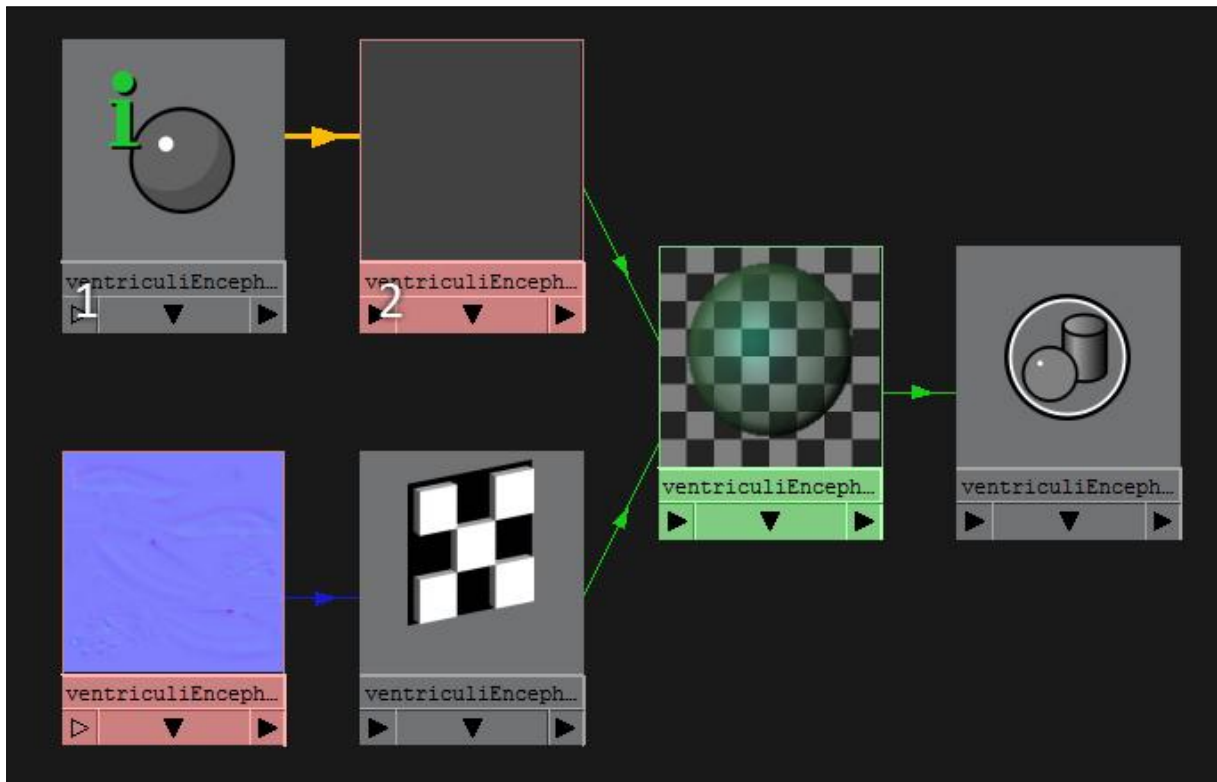

Fig. 38: Shader network

The look that I wanted to achieve was to have no transparency on the outer edges of the mesh and partially transparent in the middle. This of course has to be camera based, since the outer edge of a mesh changes every time the camera position is changed. To achieve this two nodes are necessary. The first is the samplerInfo node (1). The second one is a ramp node (2). The facing ratio of the sampleInfo node needs to be connected with the uCoord and vCoord attribute of the ramp node.

The samplerInfo node calculates the angle between the normal of the mesh and the camera. Based on this the value it picks a value of the ramp node. This means that if the angle between the normal of the mesh and the camera is 90 degrees, the value might be 1 and of the angle is 0 degrees the value will might be 0, based on the ramp input.
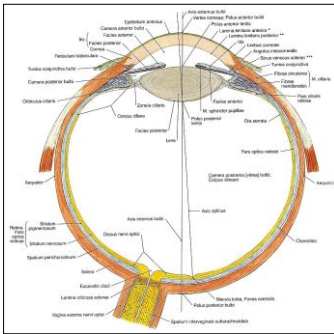
7. Eyes

Fig. 39: Eye cross section [3]

Looking at the eye it might seem like a very simple object. A sphere with a hole in it should do the trick. But this is not the case. There are so many objects that make up the eye. Especially in the lens area. Even the spherical shape has three different layers. As can be seen in the images on the side. Most of the elements don't need textures and can be shaded with simple diffuse, specular and reflectivity information. There are some elements that need to be textured like the iris and the tarsal glands.

7.1 Creation process

The first steps in creating the entire eye is making the sclera with NURBS. The sclera, choroidea and corpus ciliare. These shapes are almost perfectly spherical. Making these small changes is a lot easier with a NURBS surface then. Once they are converted to polygons the additional editing can be done like adding the optic nerve and the hole for the lens. The cross section (fig 39) is a great reference to build the shapes on top of. To make sure all of these three elements match up perfectly, the inside of the sclera should be used to create the outside of the choroidea (fig 40).
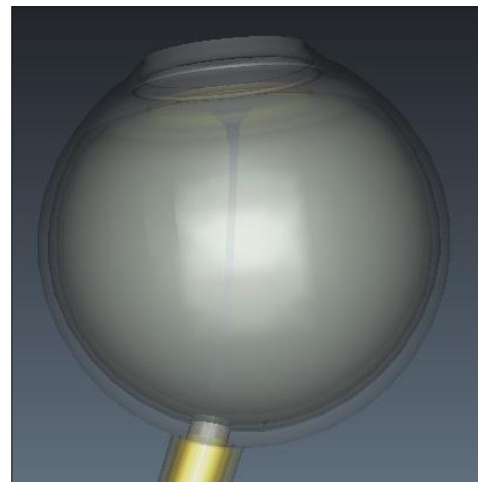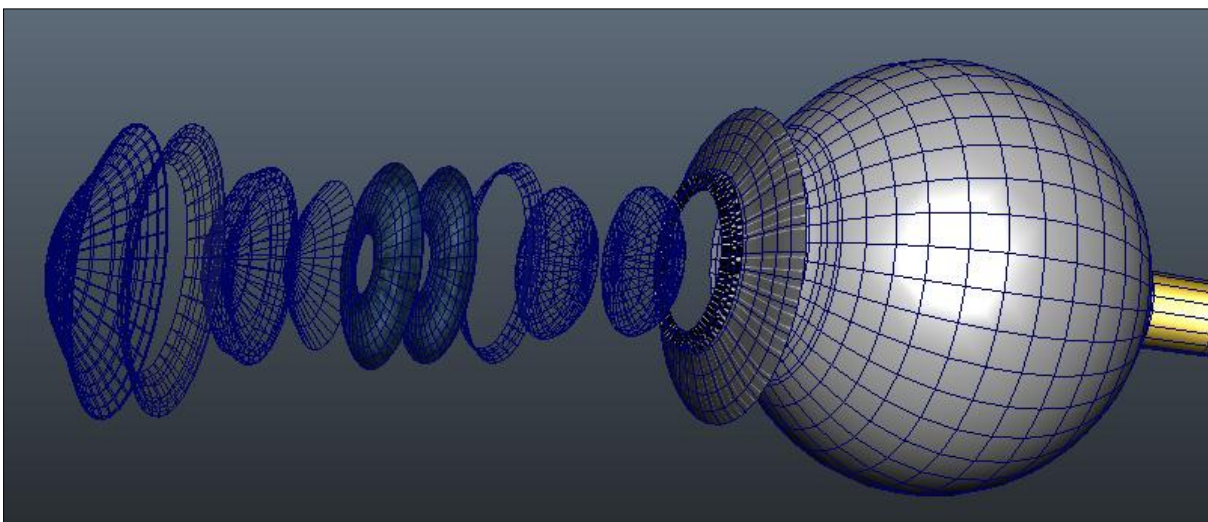

Fig. 40: X-ray top view

Fig. 41: Lens area

By finishing the sclera, choroidea and corpus ciliare first the hard part is already done. Adding all the other information is just a matter of making them fit to the sclera, choroidea or corpus ciliare. As can be seen in figure 41 there are still a lot of different objects that have to be added. The biggest issue is preventing the different meshes from intersection. All of these parts are packed up really close, and most of these parts are transparent this means that every little error will show up in the render immediately.

The same technique as building the choroidea is used. The inside of the first mesh is used to create the outside of the other mesh. By doing this I made sure that all of these objects form a perfect fit.
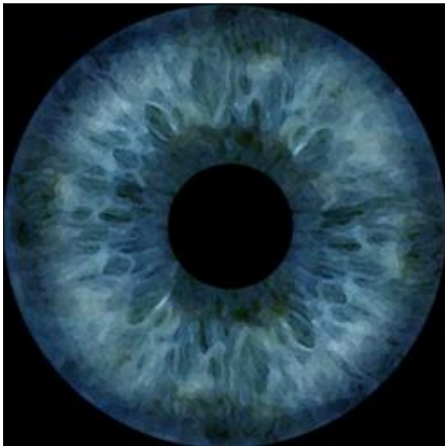
7.2 Textures

Fig. 42: Iris texture

Most of the eye shaders can be created with simple diffuse and specular information, but two objects need texture maps. These are the iris and the tarsal glands. The first step is to export the UVs to a texture map. There are loads of images of other people irises on the internet. The key is to clean this image and eliminate the reflections and other artifacts. Another issue is the realism of this texture. As been described earlier, the overall look is going to be stylized so a realistic texture would look out of place. By adding a dry brush filter the stylized look will be realized. The iris image can then be manipulated on top of the exported UVs.

There is no photo reference of the tarsal glands. This means that the entire texture has to be hand painted in Photoshop. Again the UVs need to be exported to know where the borders of the mesh will be in 2D space. Then using a Wacom tablet the diffuse information can be painted in Photoshop. Using the smudge and blur tool the desired result will be created.

Building these glands would take too much time. Therefore I download the NViDEA normal map plugin. This plugin creates a normal map from height and diffuse maps.
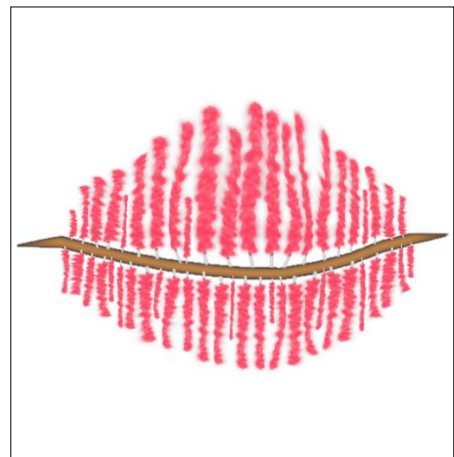

Fig. 43: Tarsal gland texture

8. Nervous system

There are a lot of nerves located in head and face area. There are twelve major nerve groups in the brain and on top of this there are also the eight cervical vertebrae nerves. This is on the left and the right side. This means that there are forty big nerve groups. They all branch and innervate each other. Figuring this out was by far the hardest part. The modeling process is quite easy since a nerve is nothing more than a tube.

8.1 Creation process

It all starts with creating the nerve path with a curve (1). This curve can then be extruded with a circle in order to create the NURBS surface (2). Small adjustments can be made like tapering or making sure it doesn't innervate any muscles it shouldn't (3). After this the tessellation settings can be set and the mesh can be converted to polygons (4). The only thing that is left will be the quadrangulation of the mesh and adjusting the UVs (5).
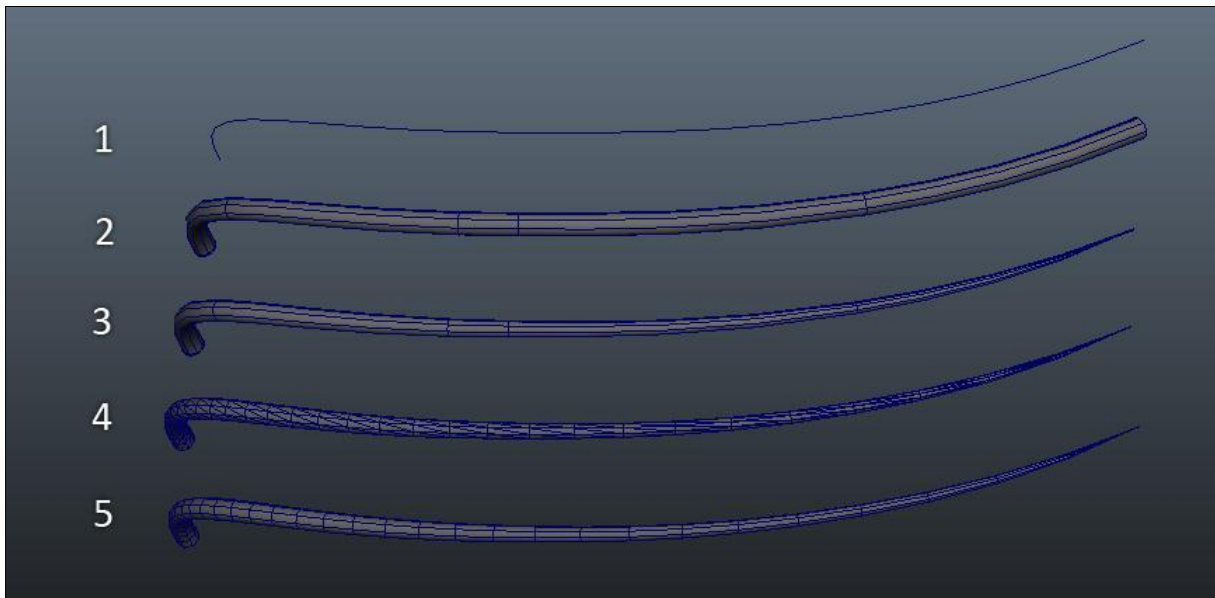

Fig. 44: Nerve creation process

The ganglia are a bit more difficult to create. Several nerves will come together at a ganglion. The key is to combine all of those nerves with the ganglion (1). There is a possibility to add extra edge loops at the connection point of the ganglion and the nerve (2). After this, using the sculpt polygon tool, the mesh can be smoothed down to create a nice transition between the nerve and the ganglion (3).
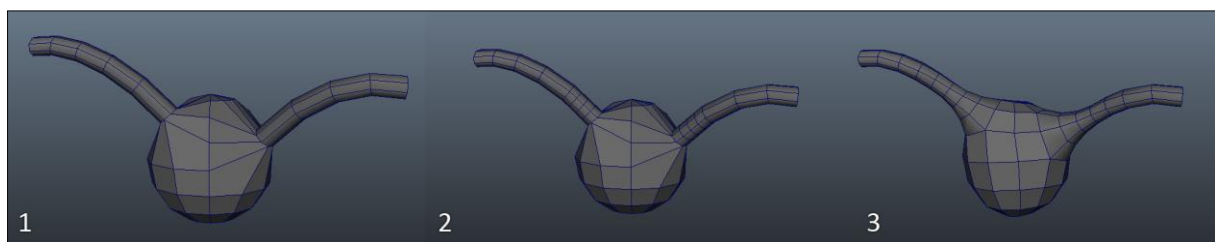

Fig. 45: Ganglion creation process

9. Lighting

The lighting set-up is a classic three-point system. This method is very common within the film and photography industry. A key light, rim light and fill light are the only three lights present in the scene. The only big difference between my set-up and a normal three-point lighting set-up is the fact that the fill light I am using is a HDR Dome light. Then all of these elements are combined with ambient occlusion and final gathering (4).

1. The key light is a spotlight with a slight yellow tint.

2. The rim light is a white directional light with a high intensity.

3. The fill light is a HDR dome light. The HDR map has been blurred to eliminate weird artifacts in the reflections.

4. The final result is created by adding these three lights and using an additional ambient occlusion and final gathering pass.
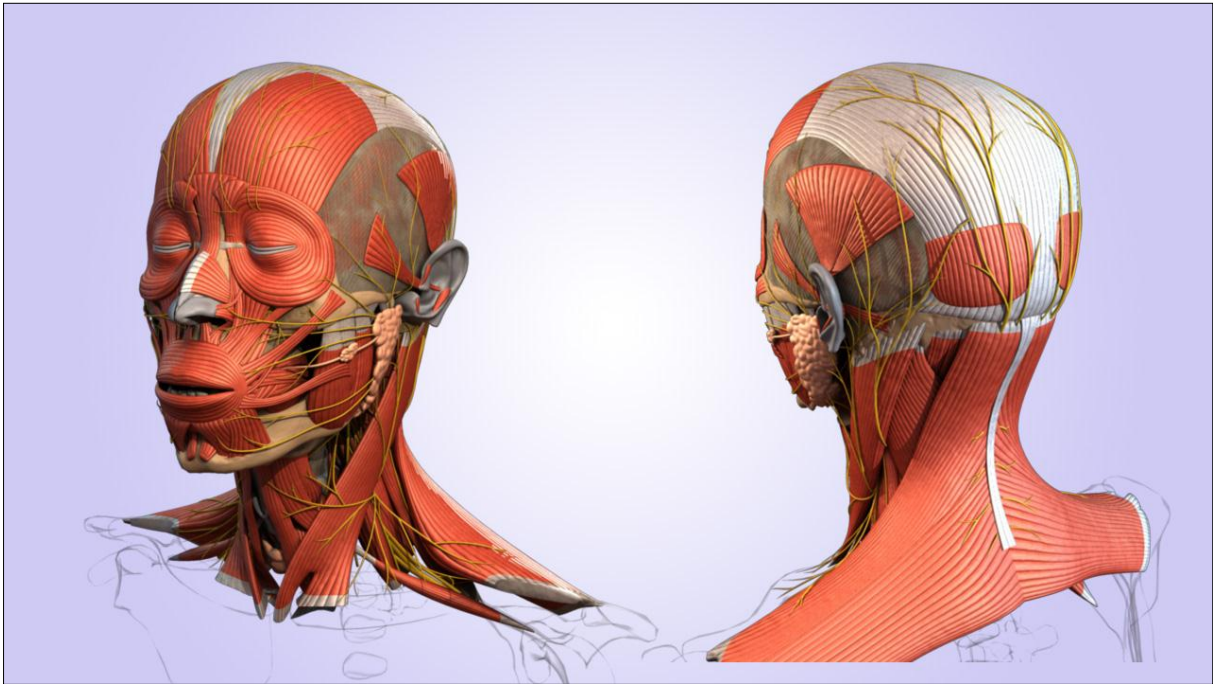

Fig. 46: Lighting examples
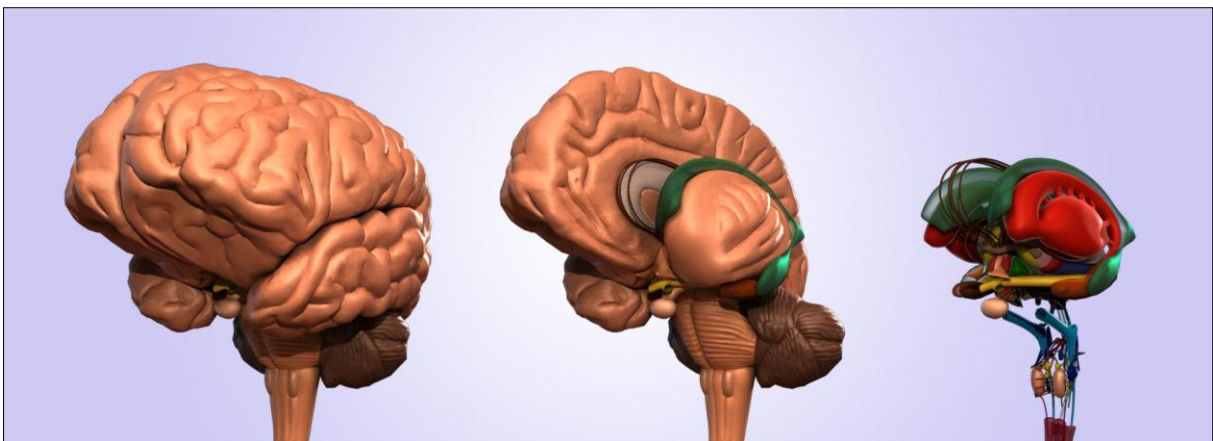
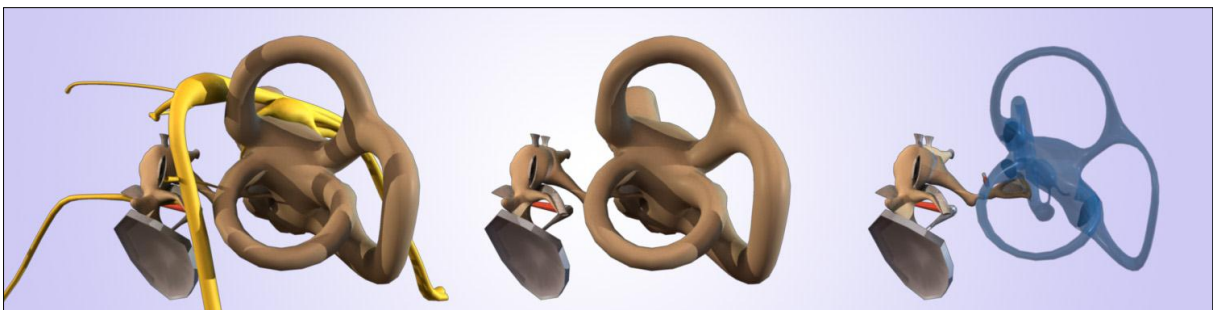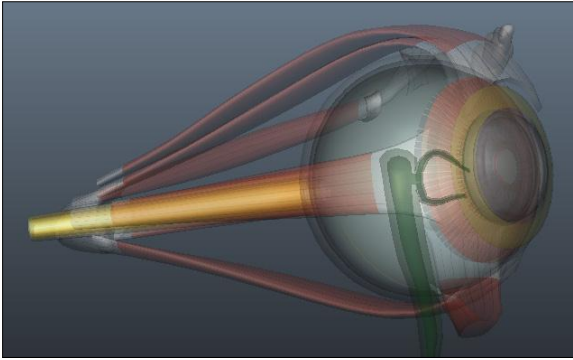# 10. Result

Fig. 47: Overall View

Fig. 48: Brain

Fig. 49: Inner Ear

Fig. 50: Eye

Fig. 51: Larynx

Fig. 52: Nerves

11. Conclusion

There are only two elements missing in this model and this is the circulatory system and the lymph nodes. Due to the already immense workload I was not able to add these aspects to the model.

Everything else is present in the model; muscles, ligaments, glandulae, nerves, cartilage, bones, eyes, tongue, the brain and the inner ear. All of the single objects that are created have proper UVs and a shaders assigned to it.

On top of this everything is properly grouped and named. This makes it easier to isolate an area of interest. Even for a person without a medical background it is a great model to get a better understanding of what the makes up a human head and neck.

I think I've accomplished in finding a balance between the real time view ability of this model and the high quality renderings it has to produce for illustrations. The additional bump information adds a lot of detail to the model but it doesn't limit the real time view ability of the model.

The biggest issue throughout the project has to be the time management. Every single object took more time than I anticipated at first. I greatly underestimated the complexity of the brain and nervous system. This messed up my original planning and in the end I had to drop the circulatory system from the project.

12. Reference

12.1 Images

[1]   http://acor.org/sgreene/praxis/bpm_infectious/images/bpm/BPM01ID21F01.gif

[2]   Gray's Anatomy
       Henry Gray, T. Pickering Pick and Robert Howden

[3]   Sobotta – Deel 1 (Hoofd, Hals, bovenste extremiteit)
       R. Putz and R. Pabs

12.2 Books

Gray's Anatomy
Henry Gray, T. Pickering Pick and Robert Howden

Sobotta – Deel 1 (Hoofd, Hals, bovenste extremiteit)
R. Putz and R. Pabs

Sobotta – Part 2 (Trunk, Viscera, Lower Limb)
R. Putz and R. Pabs