



Faculty of Science and Technology

BSc (Hons) Games Design

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Demonstrating A Full Industry Standard Character Creation Pipeline Through The  
Development Of Realistic Human Characters

by

Tom Udale

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## ABSTRACT

This project was about demonstrating a modern, standard games industry pipeline to develop realistic human characters. This project's aim was to focus more on the pipeline and implementing and demonstrating it rather than the final outcome. The outcome of this project was to create a realistic human cyberpunk character through the use of an industry standard character creation pipeline.

## INTRODUCTION, CONTEXT AND RESEARCH

The intention of this project was to demonstrate my own personal knowledge of one of the preferred development pipelines that is utilized by 'AAA' game development companies in the industry for character asset creation. The reasoning for this; to display the knowledge of each stage of the pipeline in a project, with the intention of it assisting me in getting a job in the games industry. The two main workflows for asset creation used in games are 'low to high poly' and the opposite 'high to low poly'. A low to high poly workflow

consists of creating an asset with a low number of polygons first and adding more as needed to add more detail to the mesh. High to low poly workflows involve the opposite, working from a high number of polygons first and then optimizing it to be a lower more manageable amount. There are advantages and disadvantages to both and are both viable methods.

	Advantages	Disadvantages
Low to High	<ul style="list-style-type: none"> <li>• Can be done with box modelling or poly modelling (this when the artist moves vertices, edges and faces singly by hand, this is good for accuracy and simple shapes)</li> <li>• This method usually allows the artist to dictate edge flow and topology as they go to an extent, shortening the re-topology stage later in the pipeline</li> <li>• Is useful if the character is going to be a low poly character such as a background character or mobile game character</li> </ul>	<ul style="list-style-type: none"> <li>• Not good for complex shapes or organic meshes that require less accuracy and non-symmetry</li> <li>• Can take a while to get the character to look like the intended design or concept art</li> </ul>
High to Low	<ul style="list-style-type: none"> <li>• Is easy to manipulate geometry to create complex shapes quickly</li> <li>• Is good for quickly concepting a character</li> <li>• Less accurate on a single vertex level but allows for fast inaccurate work, good for complex and organic objects</li> <li>• Once the details have been re-projected with multiple subdivision levels is easy to create a low poly version</li> </ul>	<ul style="list-style-type: none"> <li>• Can become tedious to make changes to the mesh later in the process</li> </ul>

Figure 1. Table showing the advantages and disadvantages of low to high poly and high to low poly workflows.

These advantages and disadvantages are my opinion from my experience of implementing both methods. In order to create a character that was visually appealing I researched art fundamentals which included the research of colour theory as well as shape language for the concept art stage of development and what makes a good pose including line of action which was also used for concept art and final pose design.



*Figure 2. A colour wheel used to determine complementary colours. Can be found at <https://www.dulux.com.au/how-to/how-to-use-colour/how-to-use-a-colour->.*

This research included complementary colours, which colours work well with one another. What certain colours mean in psychology and how we perceive colours and what feelings and emotions they provoke using (Olesen 2020), (*Color Meaning and Psychology – graf1x.com*), (*Meaning of Colors in Color*



## Design Shapes or Shape Language

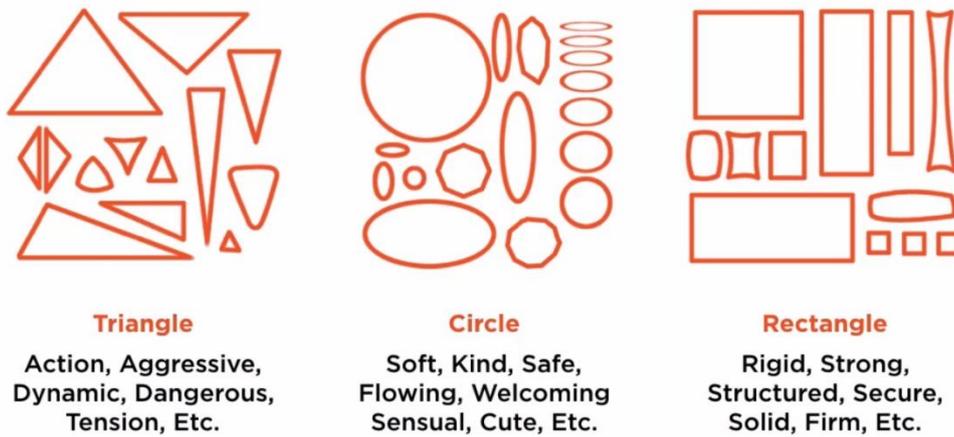


Figure 4. Image of shape language and how to use it in concept art by concept artist David Kegg (Kegg 2018).

The biggest challenge that I perceived from this project before I started it was how I was going to achieve the visuals of realistic human hair, as I had not done this before and had only done something similar previously with ZBrush's fibermesh; which allows the user to groom and manipulate individual fibres to create realistic hair or fur. The issue with this process being that it would be too strenuous on the computer and would be detrimental to performance if the character was to be used in a game and the purpose of this project was to create a character that could be placed and used in a game. The only other method that I was familiar with was the method of creating hair with polygons and modelling the hair, either with individual clumps of hair stacked on top of one another or in one mass. This method was also not viable for this character however as this project set out to create a realistic character and this method is only really useful for a stylized art style and character. The industry practices that I discovered from researching the creation of realistic hair in current AAA games revealed that industry professionals use a technique where the hair is mainly made up of an angled plane that is put back to back with another angled plane, lots of these are clustered together and modelled into the shape of the desired haircut, the look of the hair is then almost entirely provided by



As this project involved creating a character in a Cyberpunk theme, research had to be completed on what kind of character could be created and what character would fit in this world. The main point of reference for Cyberpunk lore for this project was one of the original tabletop games; Cyberpunk 2020, with the secondary reference point being the upcoming Cyberpunk 2077. Cyberpunk 2077 was mainly used as a visual aid and was only used to build upon lore that was already a part of the Cyberpunk 2020 lore. After researching the main character archetypes that were available in Cyberpunk 2020, there were three character 'classes' that were chosen as the potential character concepts: a doctor or augment enthusiast and fitter in the Cyberpunk world, a smuggler or fixer as they are known in Cyberpunk or a netrunner probably the most notorious character archetype from the Cyberpunk 2020 tabletop game, this is Cyberpunk's version of a hacker character.

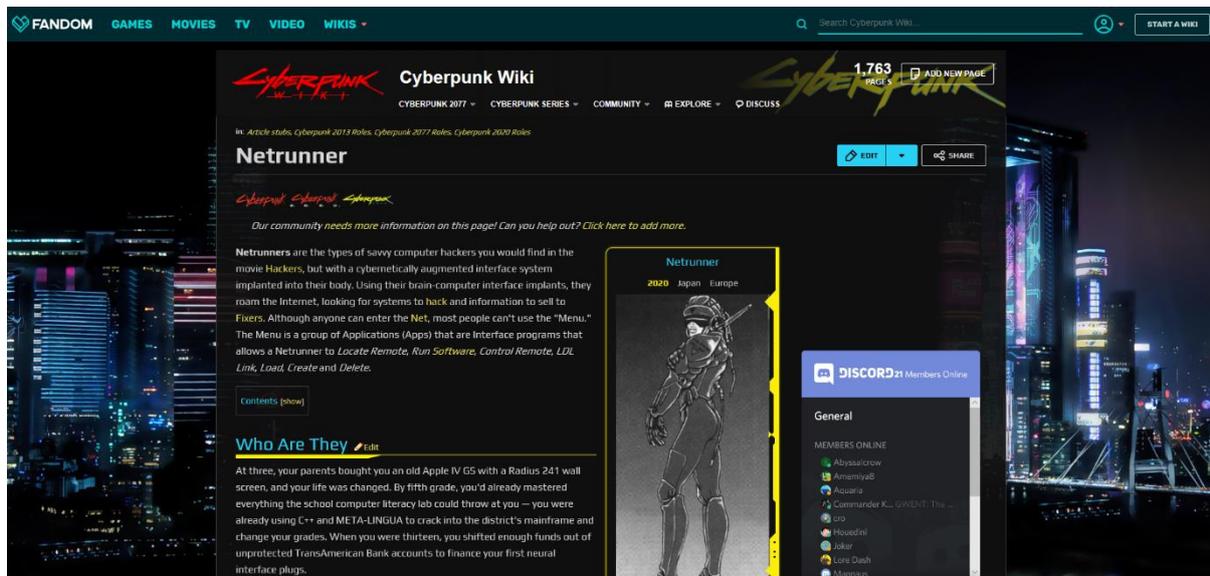


Figure 7. Image of Netrunner lore in Cyberpunk 2020. Can be found at <https://cyberpunk.fandom.com/wiki/Netrunner>.

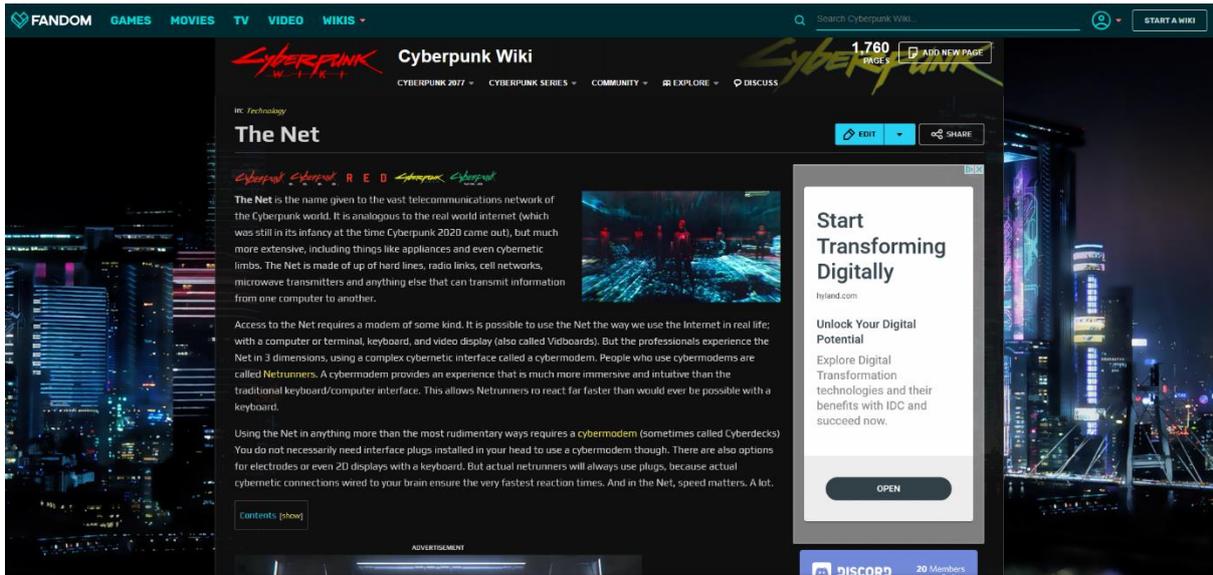


Figure 8. Image of The Net lore in Cyberpunk 2020. Can be found at [https://cyberpunk.fandom.com/wiki/The\\_Net](https://cyberpunk.fandom.com/wiki/The_Net).



Figure 9. Image of Cyberware lore in Cyberpunk 2020. Can be found at [https://cyberpunk.fandom.com/wiki/Cyberware\\_in\\_Cyberpunk\\_2020](https://cyberpunk.fandom.com/wiki/Cyberware_in_Cyberpunk_2020).

At each stage of the development process, research was completed to ensure that the development method being implemented was the most effective and efficient. As the purpose of this project was to demonstrate knowledge at each stage of development this included the concepting and design stages of the pipeline as I had not done a massive amount of concept art prior to this project. I researched the subject and good practices that industry professional concept artists follow. This meant following the practices of concept artist

David Kegg.



Figure 10. Image of silhouette character designs by David Kegg (Kegg 2018).

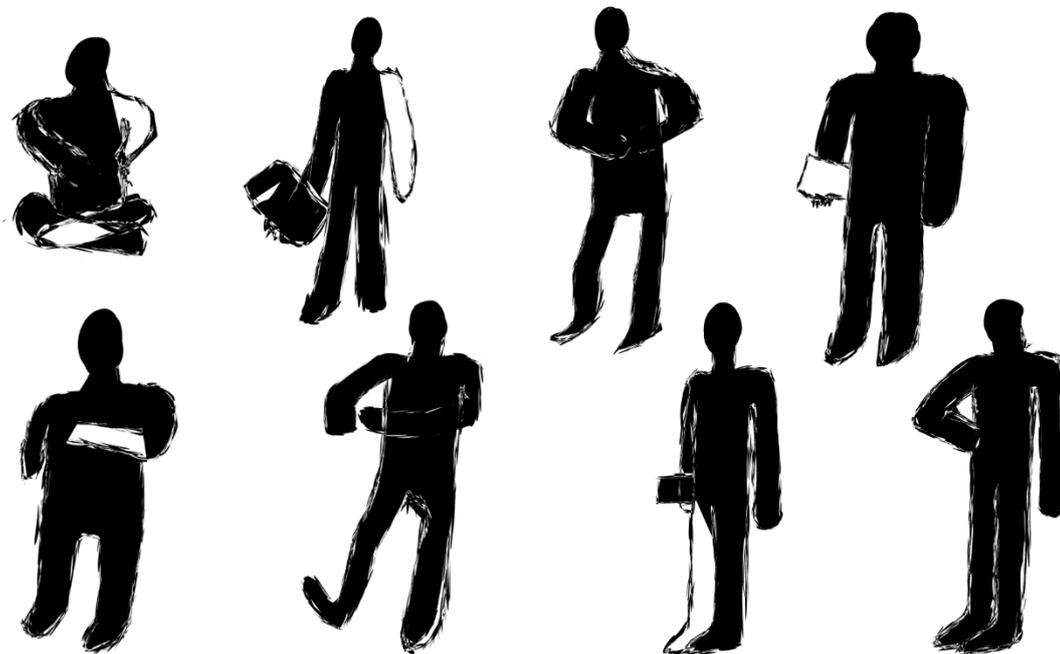


Figure 11. Image of my silhouette concepts for the initial character design, created following the same technique that David Kegg implemented.

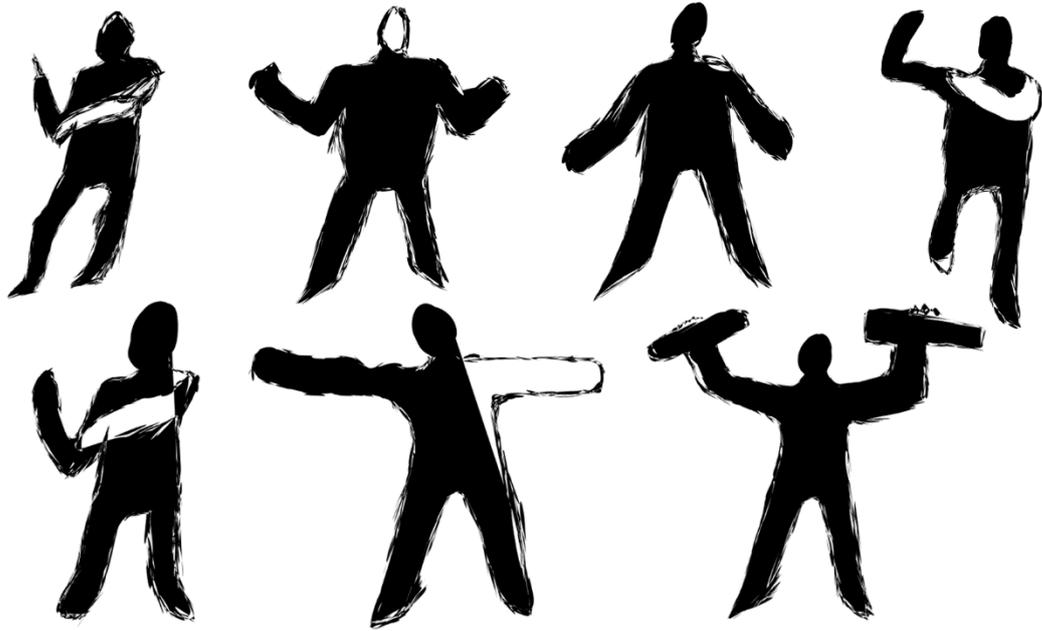


Figure 12. More silhouette concepts that I designed.



Figure 13. More character silhouette concepts that I created.

As part of the later stages of the design and concept phase of development I decided that I wanted the character to be of Japanese origin as I believe that the Cyberpunk theme and Night City have strong connotations to Japanese culture and Tokyo. Also I had not attempted to do a character of Asian heritage before and thought it would be a good challenge, this led to researching some

Japanese culture. During the research into Japanese culture I became interested in the stories that make up Japanese folklore, thinking about how this could be integrated into the character design I decided that it could become a tattoo that portrays the character's personality much like the colours used because of colour theory. According to Japanese folklore red foxes could be good or bad and were seen as tricksters and shape shifters, I thought that this was perfect for a hacker character and decided that this best represented him. A subtle way to further the nature of the character.

## DEVELOPMENT AND IMPLEMENTATION REPORT

The development pipeline that I implemented in this project was to start with a concept and derive concept art from this. Leading to modelling and sculpting, then the creation of UVs and the textures, followed by the rigging and animation phases and finally the exporting to the game engine and real-time rendering (Karon 2016), (Petit 2015), (Stefyn 2019), (Terävä 2017). I implemented a high to low poly workflow, creating high-quality assets first and then reducing the quality and faking it with textures instead of geometry so that the model could be used in a game. This creation process bakes the geometry created for the high-resolution assets as textures for the low-resolution assets, a combination of texture maps are used to make the low-resolution or 'low poly' model look as close to the high poly as possible. This technique is used to provide the best-looking assets possible while still maintaining assets that can be used in a game. A high to low poly workflow was used in creating the mesh to make it look as close to the concept art as possible. This workflow is also the optimal way for me to work with organic models and especially character models, with creating a high poly mesh first and then re-topologizing and optimizing it later. Also the way the industry is going in terms of the near unlimited poly count, that is believed to be the case for next gen consoles, in game engines such as Unreal Engine 5 as well as 8k

textures, I believe that working from low to high will soon be unnecessary and obsolete and that it will be seen as a fairly outdated workflow.



*Figure 14. Image of Unreal Engine 5 demo running on a PS5 (Unreal Engine 2020).*

As technology gets better and we move closer to better and better graphics, video games will no longer need to be as optimized as they used to, and developers will no longer need to fake as many details as they have in the past. This is why I believe that a high to low workflow is better as not as much optimization will be necessary in the near future. However, thinking that polygon budgets are not going to exist anymore is I think pretty naïve at least in the near future as the biggest reasons for them will still be for rigging and animation purposes, to avoid it being impossible for them to animate characters and to also avoid the game becoming massive in storage space. The same can be said for normal maps and other texture maps that can fake detail, I still think they will be used to make assets more manageable but normal

maps will most likely be nearly entirely replaced by displacement maps.

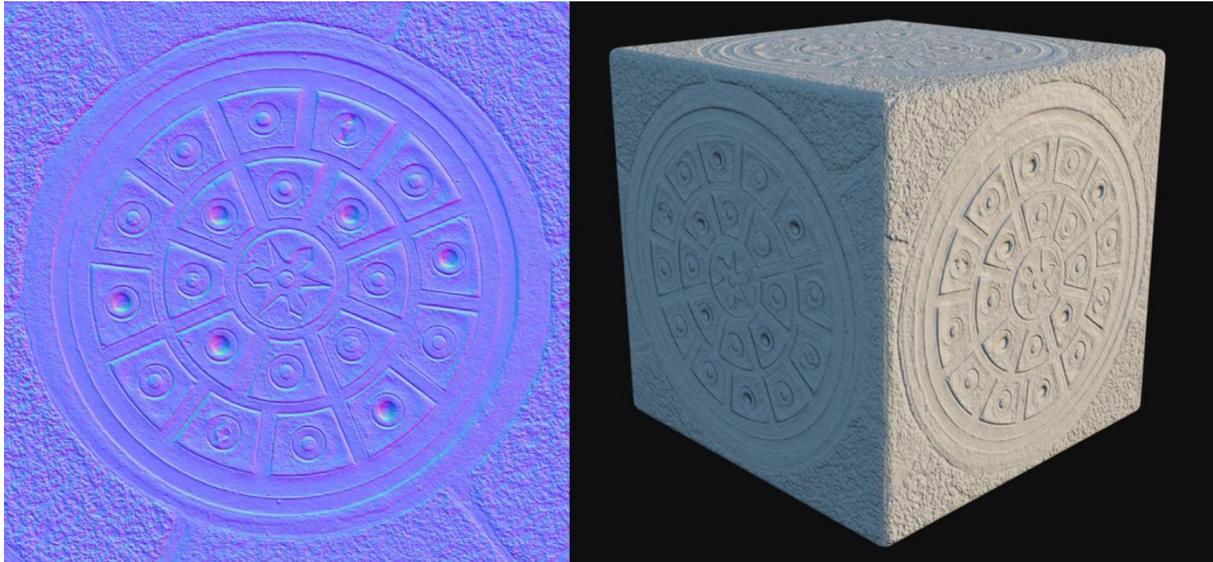


Figure 15. Image of a 3D object with a normal map applied (Lampel 2017).

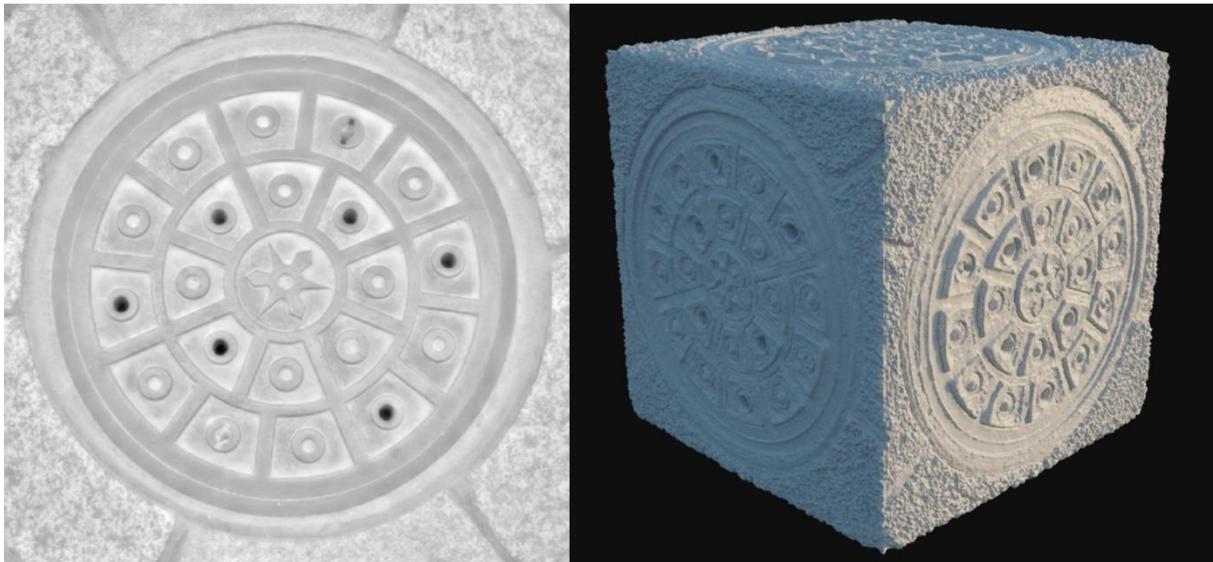


Figure 16. Image of a 3D object with a displacement map applied (Lampel 2017).

A typical high to low poly workflow for asset development and the same workflow that I implemented starts with the artist working on blocking out the character's main forms in Zbrush, this is then added upon; further detailing out the character's proportions until the character has a completed base mesh.

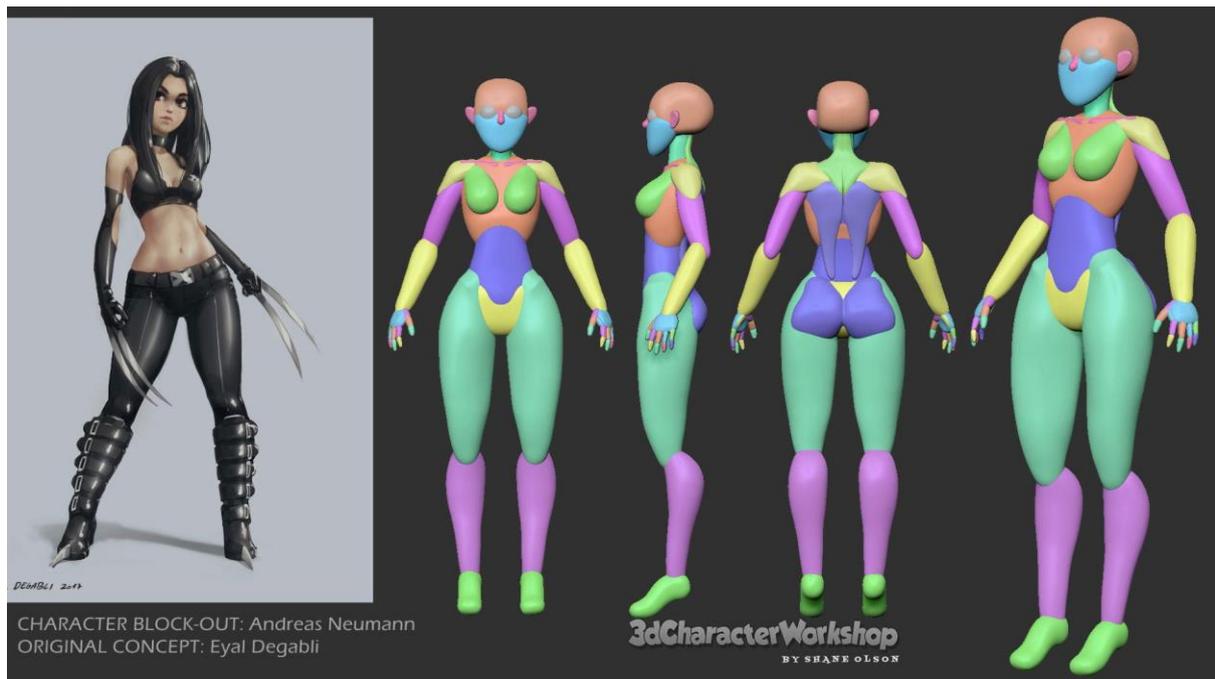


Figure 17. Image of character blocking stage in ZBrush. Can be found at <https://www.pinterest.co.uk/pin/652599802236232797/?d=t&mt=login>.

To keep the mesh manageable throughout the development process the model is often optimized to a degree at each stage of the pipeline. The first topology optimization would be implemented after the blocking stage was completed to have more manageable topology, as this is not going to be the final topology it is often done with an automatic solution at this stage and throughout the development process up until the point of the final mesh which would require retopology done by hand. The automatic topology used throughout the development process is usually done with a combination of the automatic topology solutions Dynamesh and ZRemesher. After a base mesh of the character is completed, the base mesh usually consists of just their main forms such as their overall body shape, the artist will then determine how they are going to move forward with the detailing of the character and how they will create the rest of the character such as clothes that the character is wearing. This can also be created in Zbrush or the artist could switch to software that is more specialized for hard surface modelling such as Maya or a cloth simulation software such as Marvelous Designer.

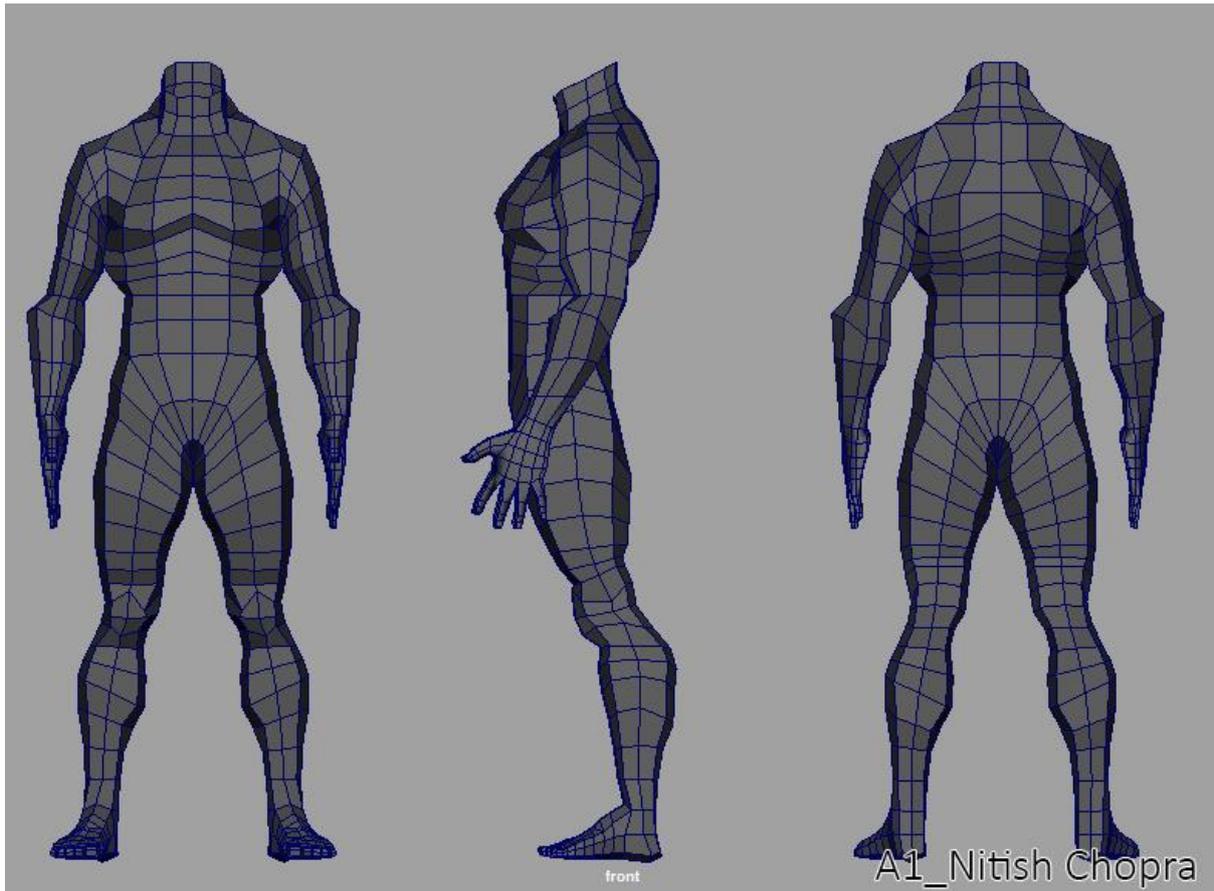


Figure 18. Image of a hard surface, low poly character model in Maya (Chopra 2020).



Figure 19. Image of a jacket created using cloth simulation in Marvelous Designer. Can be found at <https://www.notion.so/Clothes-in-Marvelous-Designer-c4f8c395a0744eef9762c47c04c3d850>.

Once the character's clothes have the desired look they will then need to be optimized with better topology, this will also be done with an automatic solution at this stage of the development pipeline. Marvelous Designer and other cloth simulation software is good for big overall shape and wrinkles but

not smaller ones that can be found on clothes in reality, these will need to be hand sculpted in Zbrush by the artist to make the garment look more realistic.

Once the mesh has been created to look like the concept art and the hair and clothes have also been created then the artist will start to optimize the mesh, this stage of the process is called retopology and involves the artist exporting the mesh into a programme such as Maya and using the created mesh as a base to draw polygons of another mesh over the top of it.



*Figure 20. Image of a re-topologized shirt (Thuc Le 2016).*

Once the mesh has been re-topologized it can be sent back to Zbrush, as the new re-topologized mesh will have lost some of the details of the original mesh, the new mesh will need to be subdivided to a similar poly count as the original and the details of the original will then need to be re-projected onto the new mesh.



Figure 21. Image of ZBrush re-projection being used on a character model after retopology (Flipped Normals 2018).

Once this process has been completed and the re-projected mesh has been cleaned up of any distortions left by the automatic reprojection solution, the mesh will have multiple subdivision levels inside of Zbrush, one of the lower subdivision levels can then be used as the low poly mesh and the highest subdivision level, the one that looks like the concept art can be used as the high poly mesh.

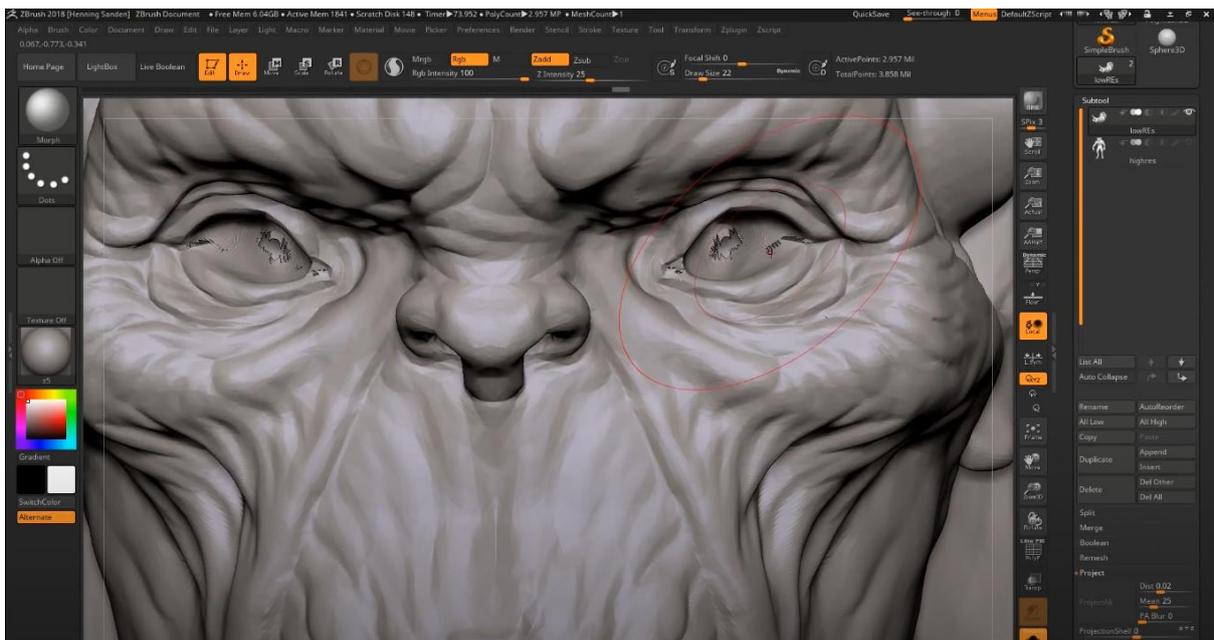


Figure 22. Image of distortions that are presented sometimes after re-projection (Flipped Normals 2018).

The high and low poly meshes will need to have UVs generated in traditional modelling software such as Maya so that they can be textured, these are 2D texture coordinates that are required for texturing.

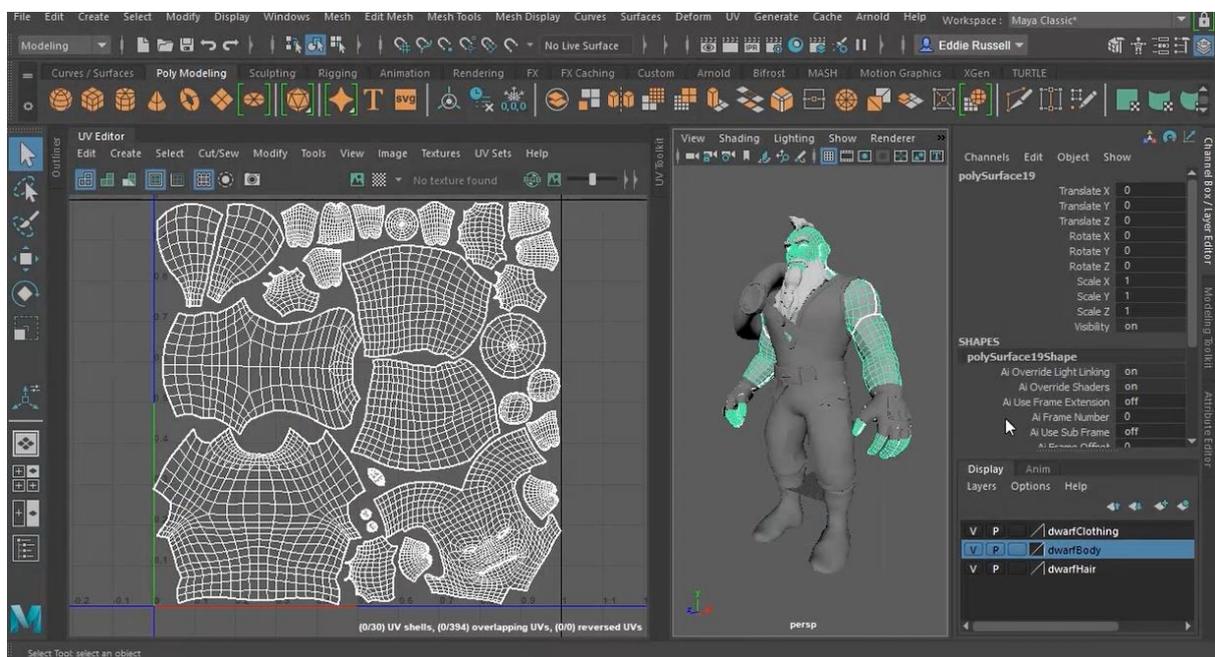


Figure 23. Image of a character and its UVs in Maya. Can be found at <https://learn.unity.com/project/uv-mapping-game-characters-in->.

UVs are a 2D layout of the polygons that make up the 3D mesh. In order for the UVs and the textures to function properly they need to be inside one UDIM (U-Dimension) as only one UDIM can currently be used in games and the UVs must not be overlapping each other, the UVs are split up into shells to allow for texture seams. The artist will determine where the texture seams will be placed by cutting along some of the edges of the mesh and then unwrapping it, making it 2D for the UVs. The artist usually tries to hide the texture seams under items of clothing or where the player is less likely to look such as the inside of limbs or the bottom of the mesh. Once this has been completed for both the low and high poly meshes they can then be sent over to Substance Painter so that the texturing process can be started. Substance painter allows the user to select the low and high poly versions of the mesh, baking the high onto the low automatically once the textures have been completed. Textures can easily be applied and painted in Substance Painter and textures can be created in Substance Designer. The use of Substance Painter and the creation of procedural textures, textures that are generated from nothing on a

computer, is the most common method used for texturing in AAA games being developed now. The other method being the more traditional and slightly outdated in my opinion, the method of creating the textures in Photoshop from a photograph. This method involves ensuring that the texture is seamless if it needs to be, meaning that it will tile without there being any obvious seams if it is needed to, this method also involves painting the other texture maps that are needed for the minor imperfections and detailing by hand including normal maps, roughness maps, height maps, displacement maps etcetera.

The low poly mesh will now be the only mesh needed as the high poly mesh has been baked into the textures of the low poly mesh. The low poly mesh will then be rigged in Maya, giving the mesh bones and joints that are connected to it and that can then be animated.

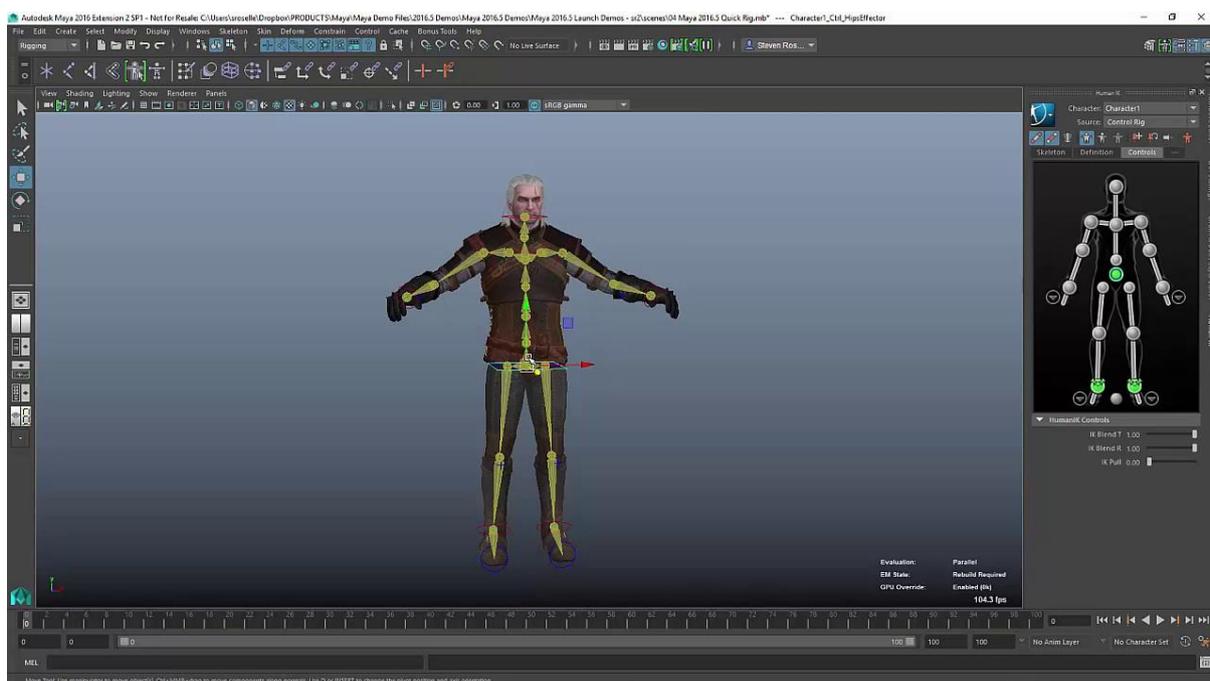


Figure 24. Image of bones being placed on a character in Maya for rigging (My Oh Maya 2017).

After the bones of the character have been placed the character will need to be connected to them, this is a process known as skinning. After the character's bones have been skinned to it, each part of the character that is connected to the bones will need to be weight painted, this is the process of determining what parts of the model need to be connected to which bones.

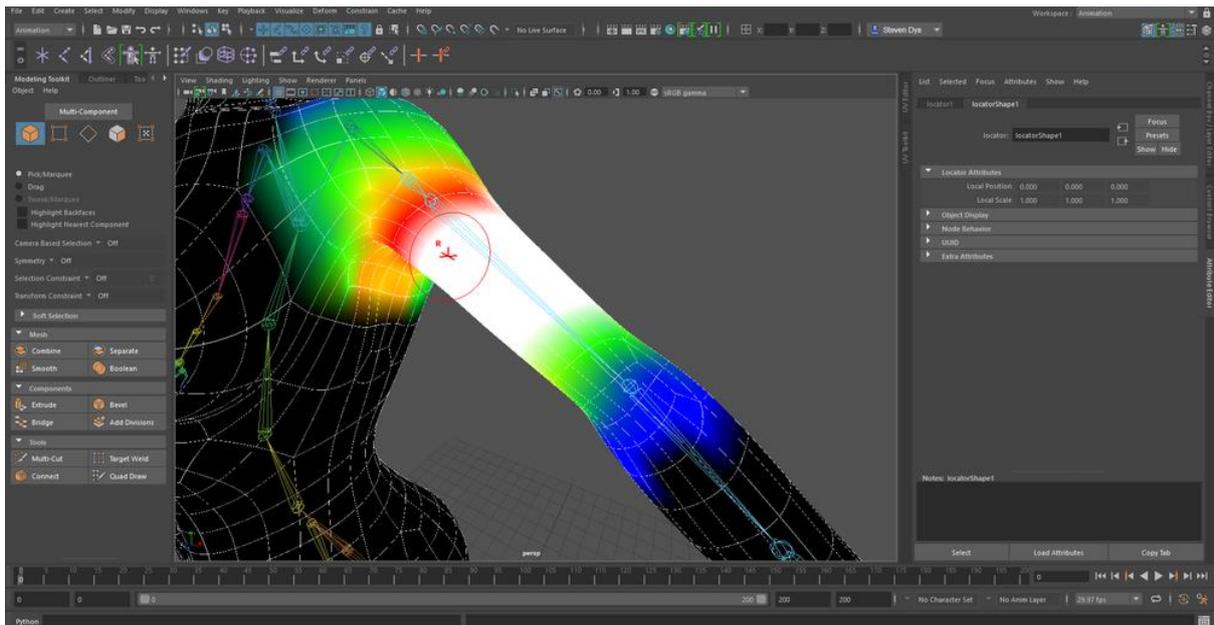


Figure 25. Image of weight painting in Maya (sndye 2017).

The bones will then have controls created for them so that the animator can easily manipulate them.

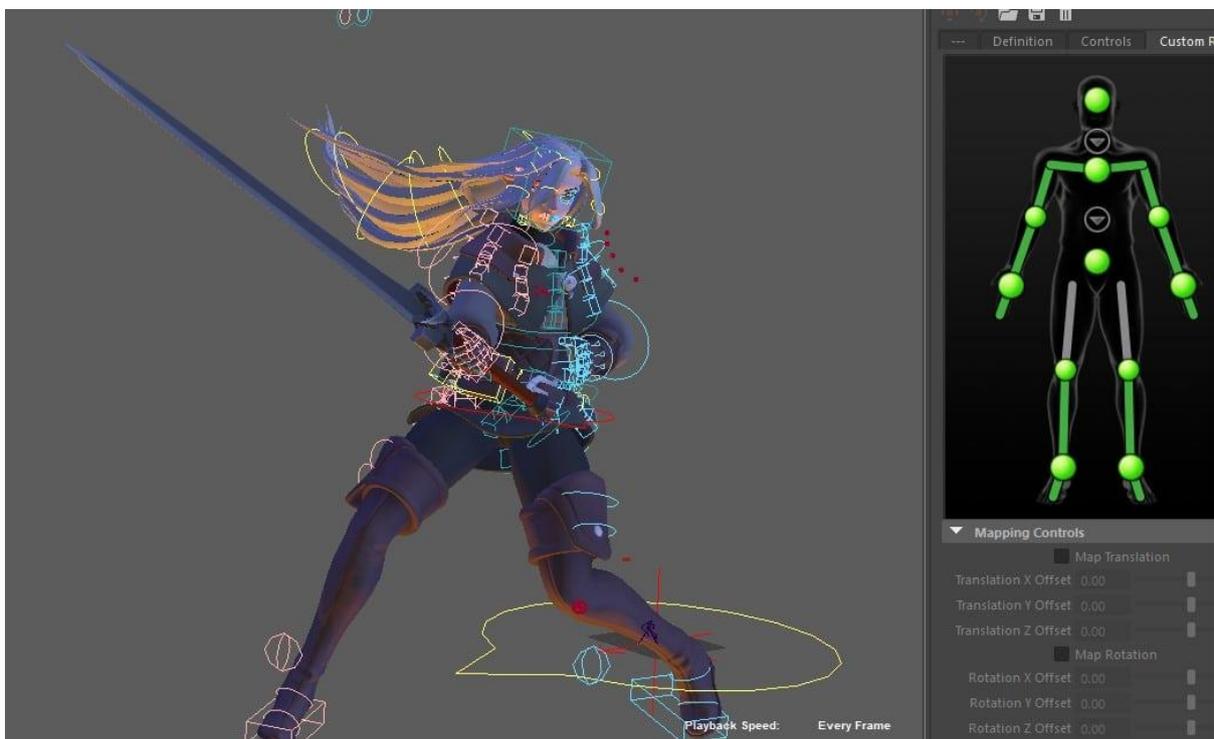


Figure 26. Image of rigging controls in Maya (Rigging Dojo 2019).

The character is then animated by moving the controls, which control the bones of the character into the desired position for the start of the animation. This pose is known as the first key pose, this pose is then keyframed at frame one basically saving the pose on that frame. The character is then positioned into the second key pose and keyframed at frame thirty as modern games run at sixty frames per second and this pose is the middle of the animation. The final key pose is placed at the final frame, this being frame sixty. If the animation is required to loop then the key pose is set as the pose one frame before the first key pose. The in-betweens or the poses that are on the frames in between the key poses are generated automatically by Maya but often need editing and fixing by the artist (Williams 2008).

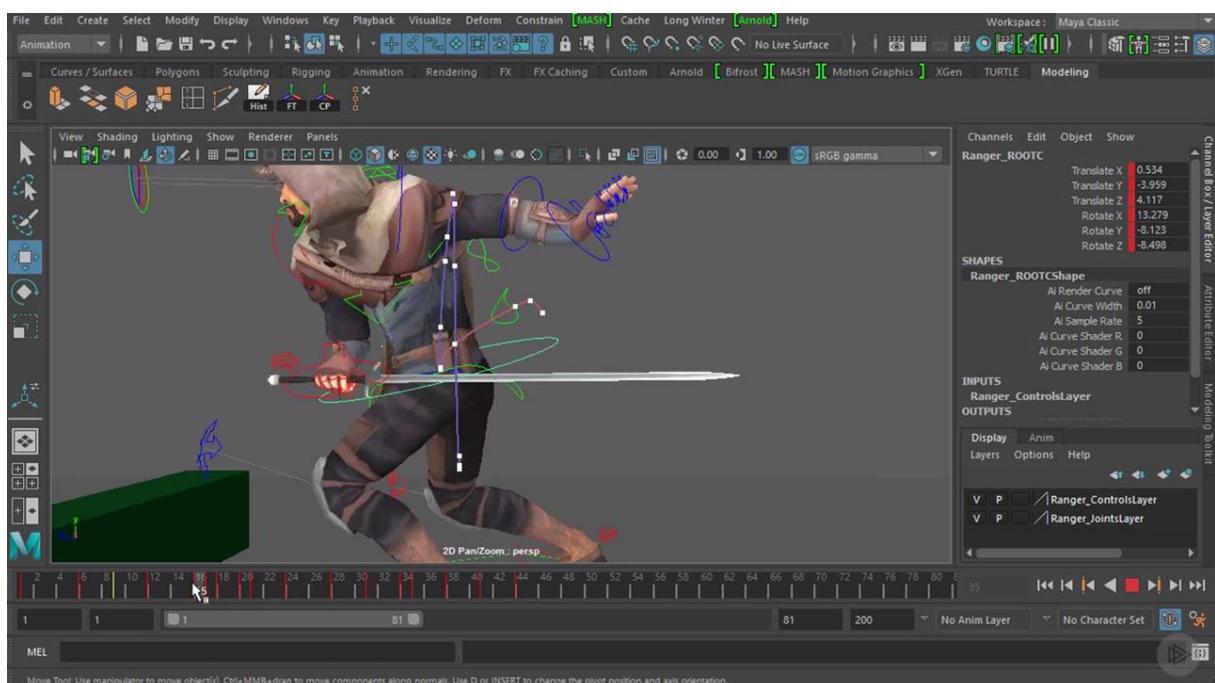


Figure 27. Image of animation in Maya (CG Society 2020).

This process will be repeated for each animation and then the model and all the animations will be exported ready to be used in the game engine.

Once the mesh has been exported from the modelling software and imported into the game engine, the textures will need to be applied to it through the use of a material which combines all of the texture maps into one texture.

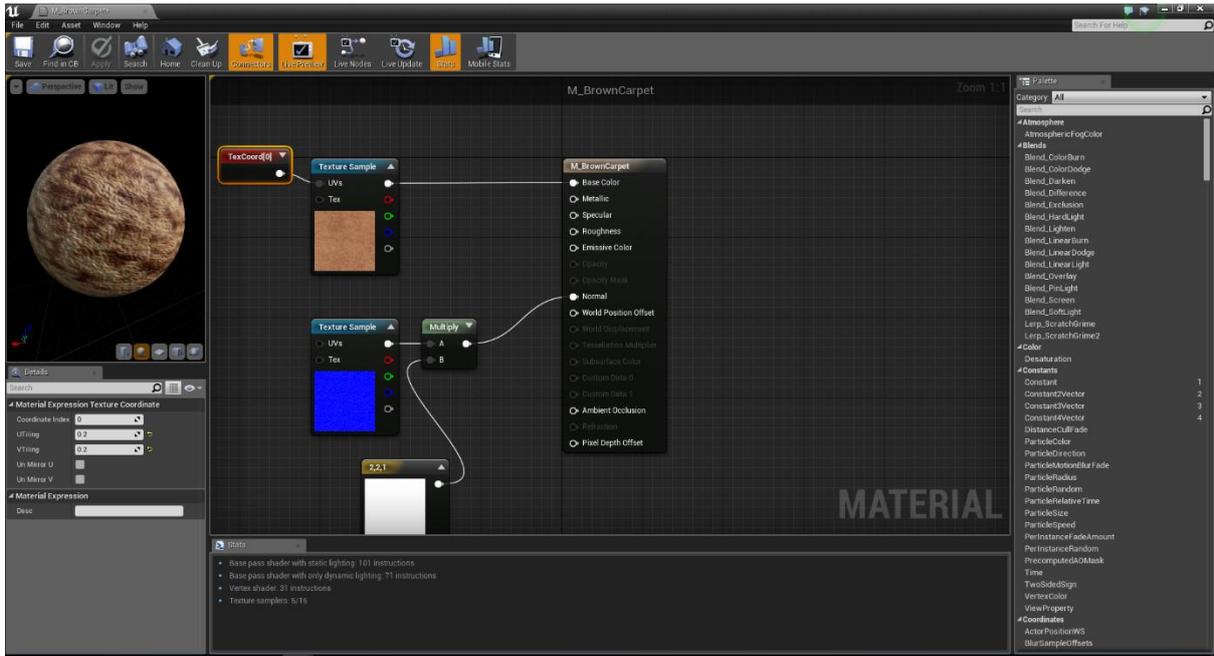


Figure 28. Image of a material in Unreal Engine 4 (JohnDiCamillo 2016).

The animations will also need to be applied depending on the character’s scenario and the player’s actions. This is done through the use of a state machine, which determines what state the character is in and what animation needs to be played based on this.

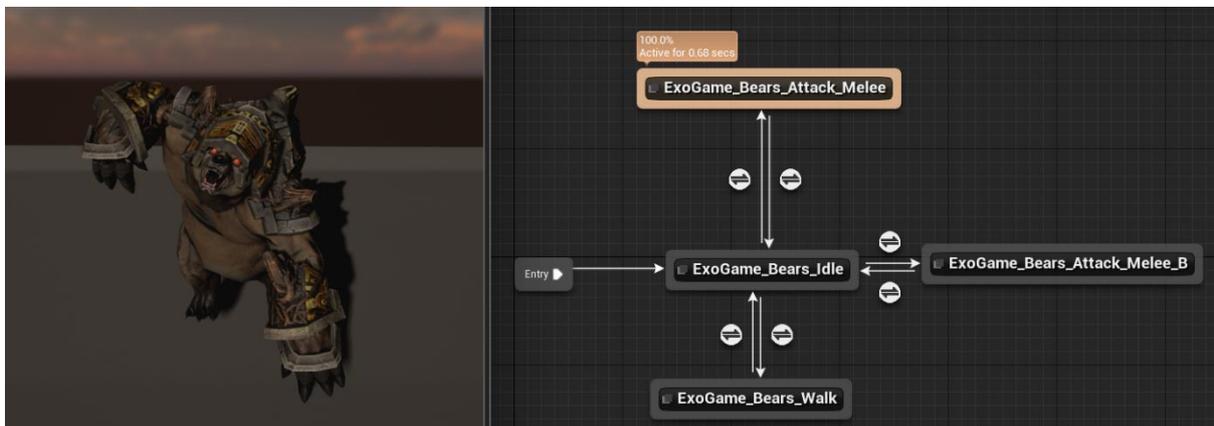


Figure 29. Image of a state machine in UE4. Can be found at <https://docs.unrealengine.com/en-US/Engine/Animation/StateMachines/index.html>.

The asset has now been completed and has been developed from concept to finished textured and animated mesh inside the game engine.

My development process started with idea generation, as the theme for the character was Cyberpunk I created a moodboard for both a male and female character as I was not sure which gender I wanted the character to be to begin with.

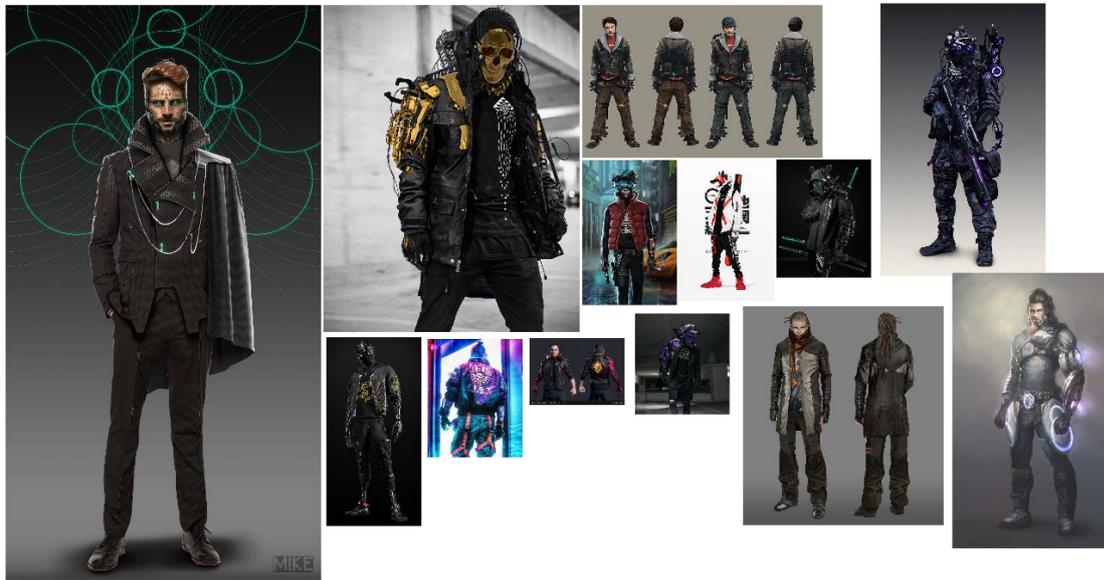


Figure 30. Image of the male character moodboard I created for idea generation.

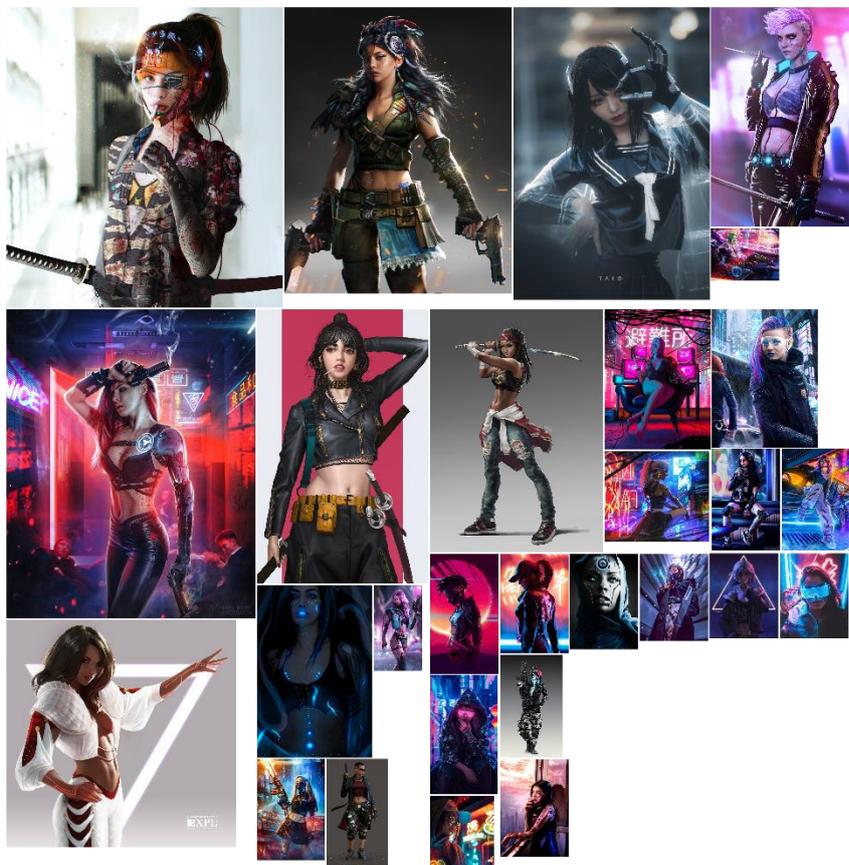


Figure 31. Image of the female character moodboard I created for idea generation.

I generated six different characters that I could create in a word document, after this I decided I wanted to create a male character. I was using the same concept art techniques as concept artist David Kegg which meant starting from creating a silhouette of what the character could look like in a pose that suited that character. This method was used to focus on the minimal amount possible of the character and to mainly focus on their main forms, I also used pose design and what makes a good pose by Daniel Floyd (Floyd 2018). I used these moodboards as well as the Cyberpunk lore that I researched and the silhouette sketches that I created to generate some initial ideas about the appearance of the character. Using these three concept art generators I created the concept art for my character and used an image of myself in the character's pose to ensure that the body proportions were correct. After the sketch was completed I added colour and shading, on top of this I experimented with the colours based on the aforementioned colour theory research.

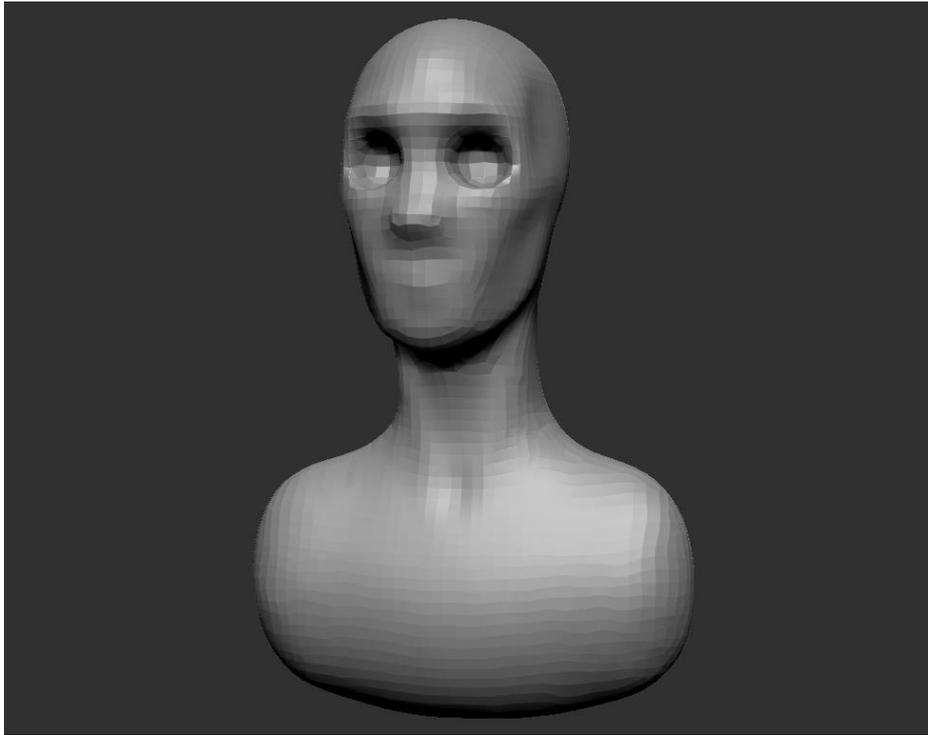


*Figure 32. Image of the first three colour variations I trialled for my character.*



*Figure 33. Image of the second three colour variations I trialled for my character.*

When deciding on which workflow to use for the 3D work, I have used both workflows in the past depending on the character that I am creating, however as I knew the character for this project was a main character I decided to implement the high to low poly workflow. This meant creating a character from scratch which in a low to high poly workflow is usually done with a cube, however, as the opposite method was being implemented in this project a sphere was used as the starting point as the shape of it is similar to the shape of the head.



*Figure 34. Image of the initial character blocking stages.*

The initial stage of the workflow was to block out the character's main forms. I shaped the sphere to be more of a head shape and also extruded the bottom of the sphere to create the neck, shoulders and upper torso region.



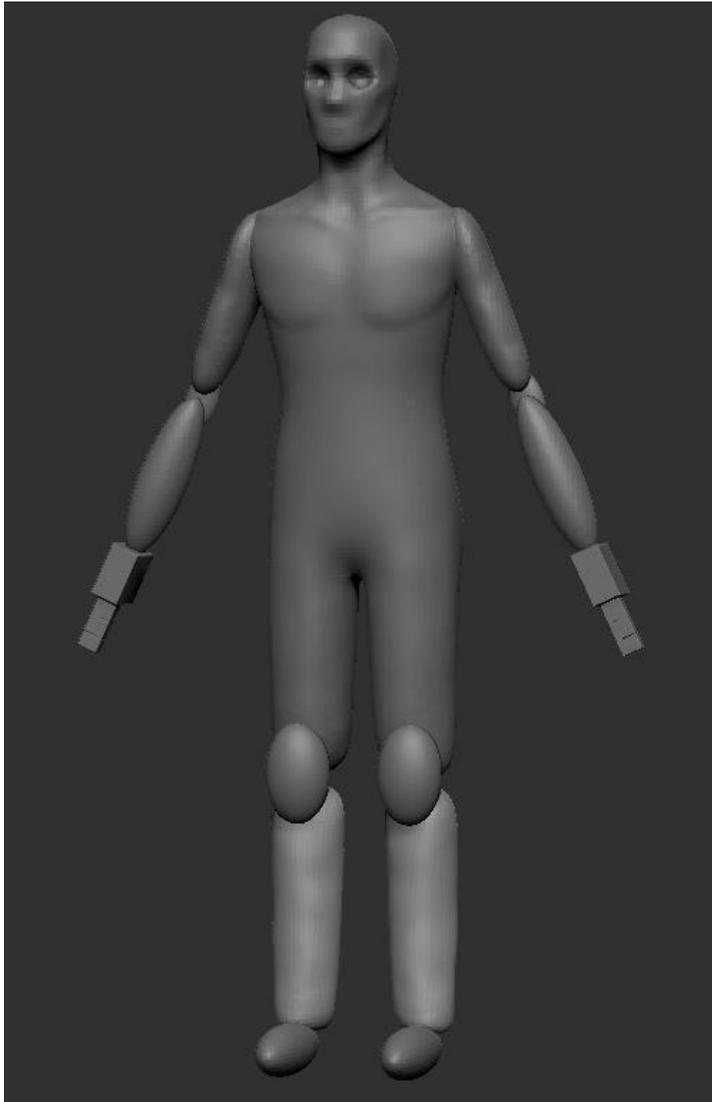
*Figure 35. Image of the initial stages of adding the limbs.*

When I create high poly characters in ZBrush I like to break up the main forms and body parts into separate subtools, through this method I created the arms and legs separately, this was done with the use of more spheres that were extruded in length to better match the general shape of arms and legs. I also began to sculpt the torso further, extruding more from the shoulders and upper torso that I had already created and refined the body proportions. I further added to the character's form by adding a slightly elongated sphere for the kneecap and another elongated sphere for the lower leg.



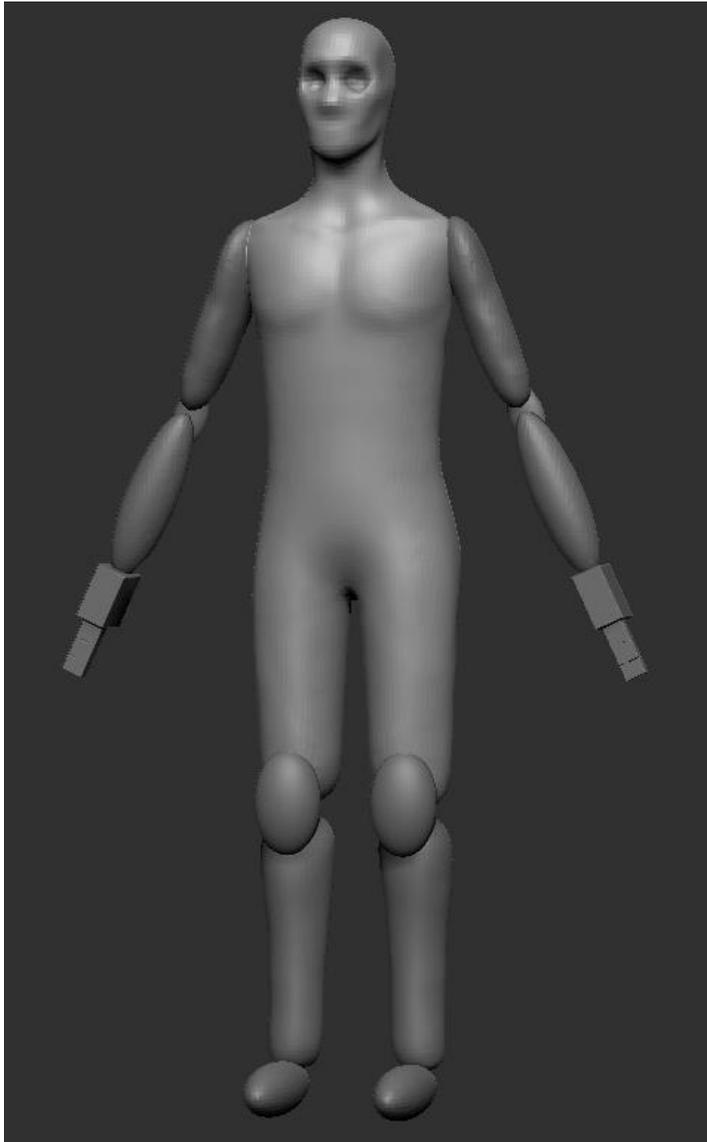
*Figure 36. Image of further adding to the limbs and the first steps of defining the torso.*

I further refined the character and anatomy details by sculpting landmarks for the torso, this includes the clavicle, pectoral muscles, sternocleidomastoid muscles, the gluteus maximus and the scapulae. These landmarks were used in addition with duplicates of the character's head to ensure that the rest of the body was in proportion to the head, this was under the guidance of the anatomy book 'Anatomy For 3D Artists: The Essential Guide For CG Professionals' (Nagulov 2015) that stated that the human body is approximately eight heads tall. The next stage was to continue to add the remaining limbs that had not been added, including the elbows and lower arms, hands and feet.



*Figure 37. Image of further developing the limbs and mirroring them to the opposite side.*

These were all also created with spheres and sculpted to form the shape of the limbs. The limbs were then mirrored to the other side. As the model is still in the blocking stages at this point, it is easy to make large changes and adjust body proportions. After receiving feedback on the initial blocking stage of the character I noticed that the character appeared to be slightly leaning forward, this was fixed by adjusting the rotation of the torso from the hips. I continued to refine the body, bringing the waist in and further shaping the pectoral muscles, gluteus maximus and scapulae.



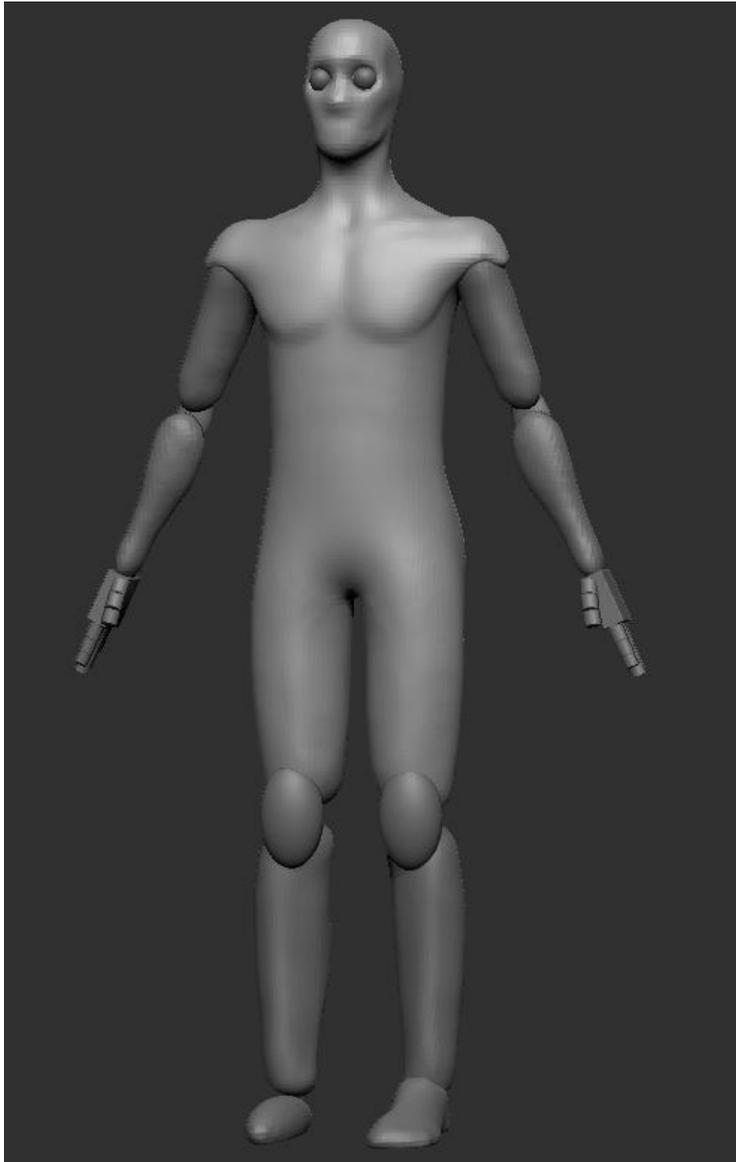
*Figure 38. Image of further definition of the torso and the limbs.*

Further shaping and sizing of the limbs was done as they were out of proportion from the rest of the body. I created individual fingers out of cylinders and the palm of the hand from a cube also further refined the shape of the head and the skull and started to block in the facial features.



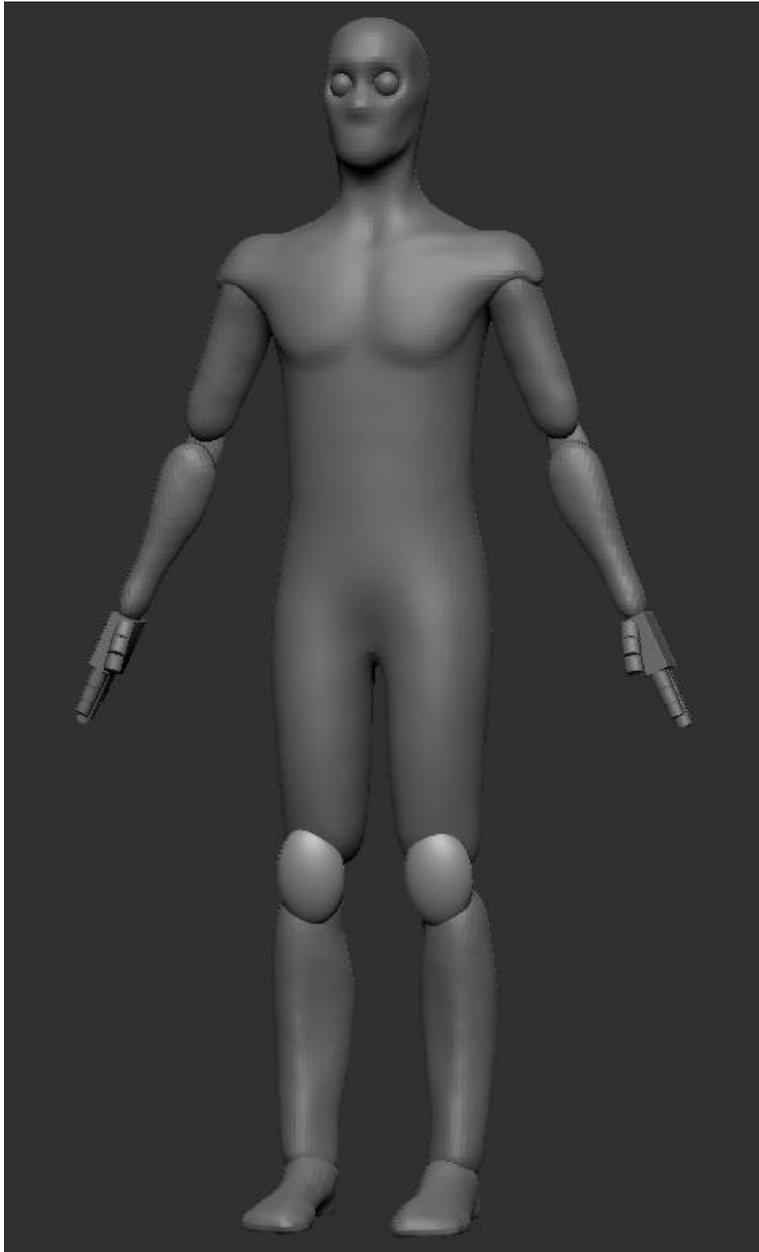
*Figure 39. Image of continuing to define the arms and the head.*

Next stage was to continue to further develop the appearance of the forearms and insert the deltoid muscles and further extrude the shoulders so that they would be wide enough to connect the arms to the torso.



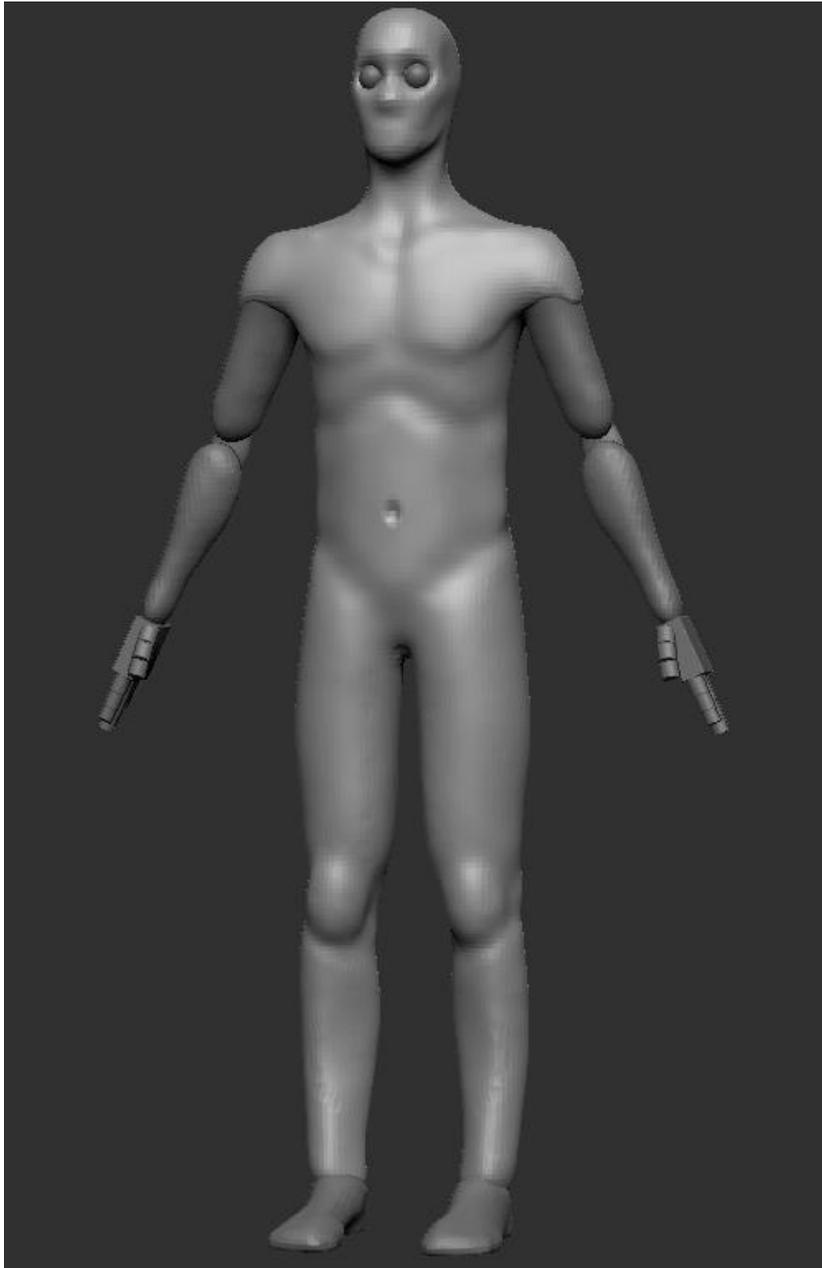
*Figure 40. Image of shape overhauls for the limbs, making them more realistic.*

Massive overall shape overhauls were completed on the lower legs and feet, making them appear a lot closer to how they should.



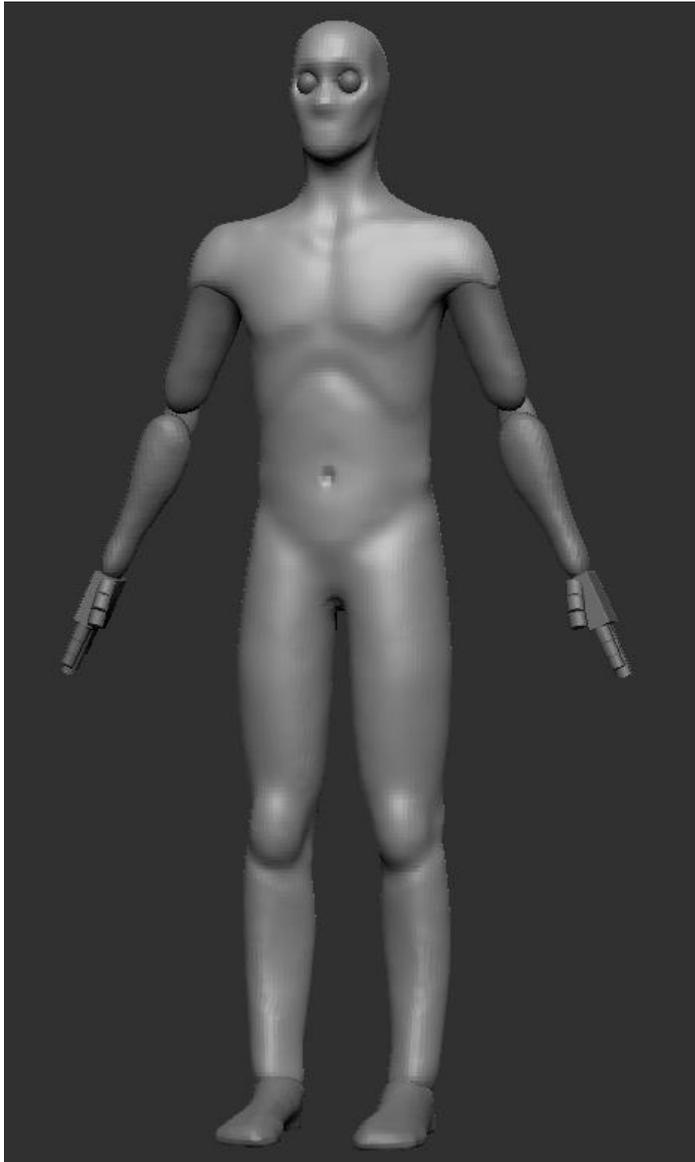
*Figure 41. Image of defining the legs and knees to be more realistic.*

The knees, hips and upper legs were also better proportioned with the rest of the body. At this stage I started to connect the subtools together and merge the body parts into the torso. Starting with the legs I merged the upper and lower legs with the knee and filled in the gap that was behind the kneecap as well as smoothed the appearance of the merged subtools.



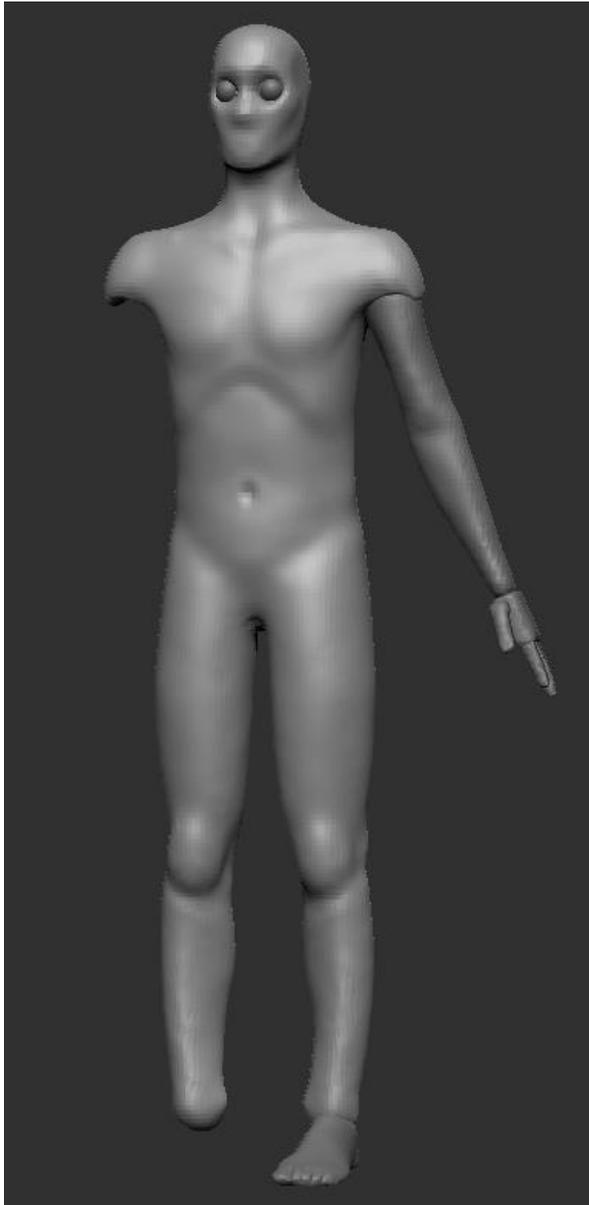
*Figure 42. Image of continued definition of the torso and merging of the subtools of the limbs.*

Continued to add more of the landmarks of the torso including the bottom of the thoracic cage and the navel as well as refined the shape of the legs and the gluteus maximus.



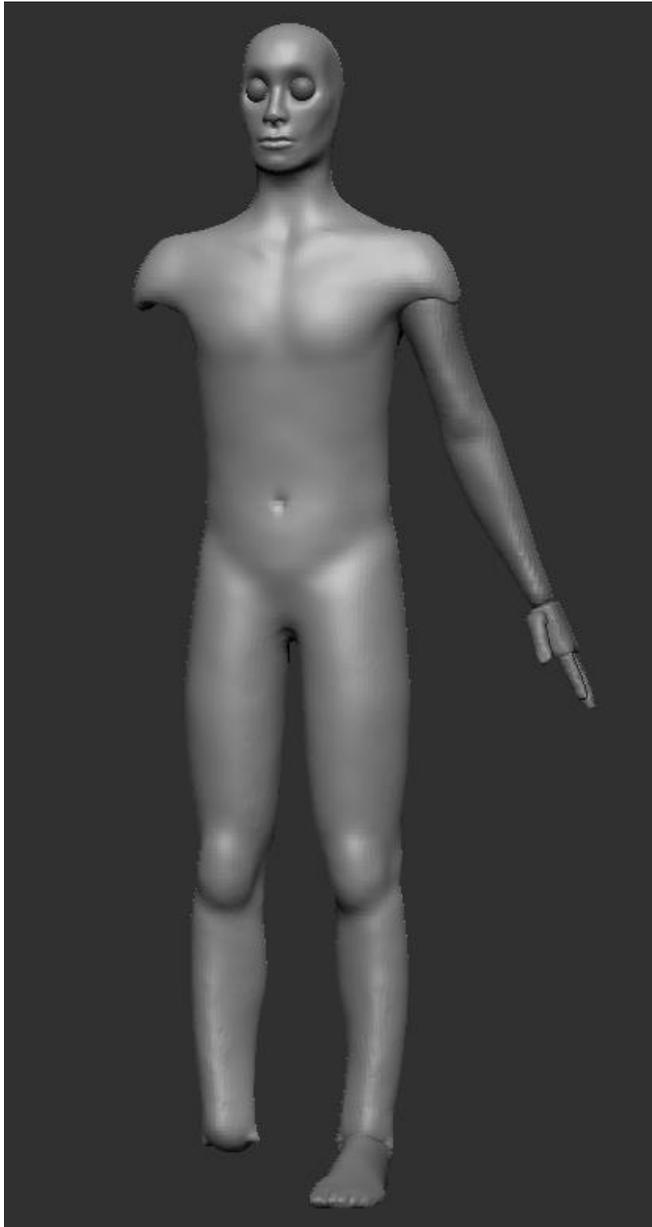
*Figure 43. Image of the lower limbs being improved and mirrored and merged.*

The parts of the arm, upper arm, elbow and lower arm were then merged together, smoothed and filled out with volume to better fit the body proportions and to eliminate the voids that were present in the blocking stage when they were separate objects.



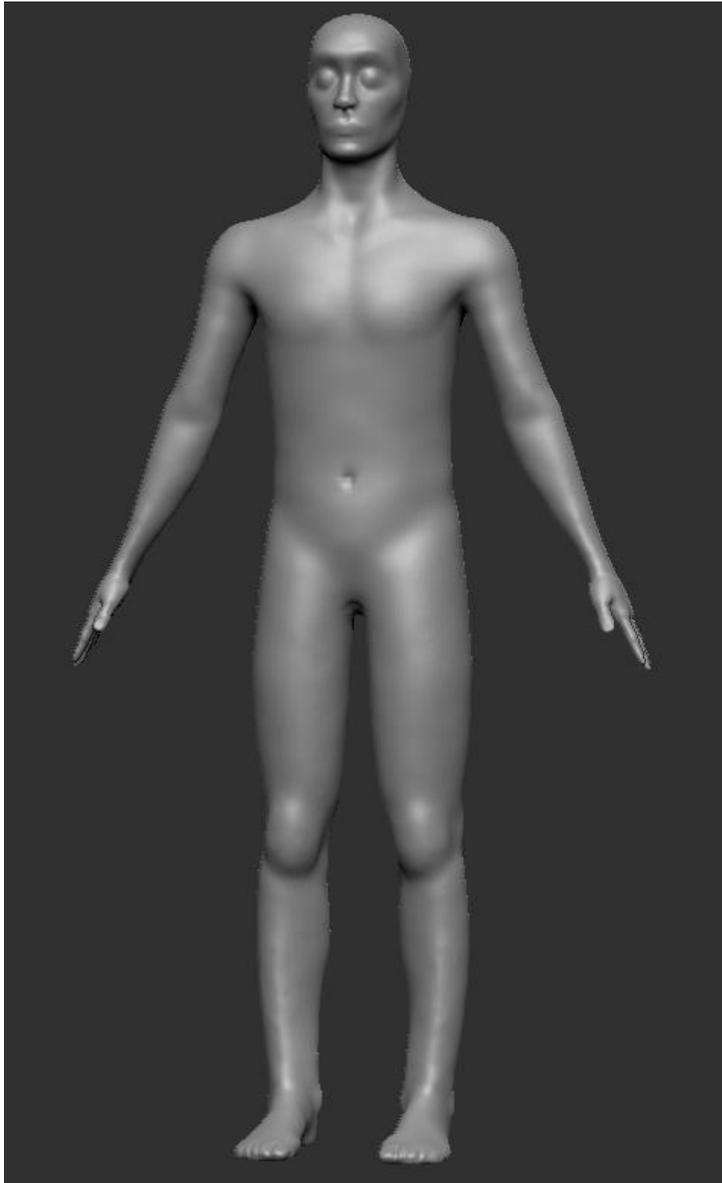
*Figure 44. Image of merging of the arm subtools and definition of the foot.*

The next phase was developing the hands to be more realistic and less primitive and making the landmarks that were used to ensure that the body was in proportion, were smoothed and less prominent to make the character more realistic.



*Figure 45. Image of making the torso more realistic and definition of the ankles.*

Further refinement of the face and facial features as well as the back, feet; including the definition of the toes and ankles.



*Figure 46. Image of the finished mesh before it was sent to Marvelous Designer to be used as an avatar for the clothes to be created.*

The blocking stage of the mesh had been completed and the body base mesh was sent to Marvelous Designer so that the clothes could be created.

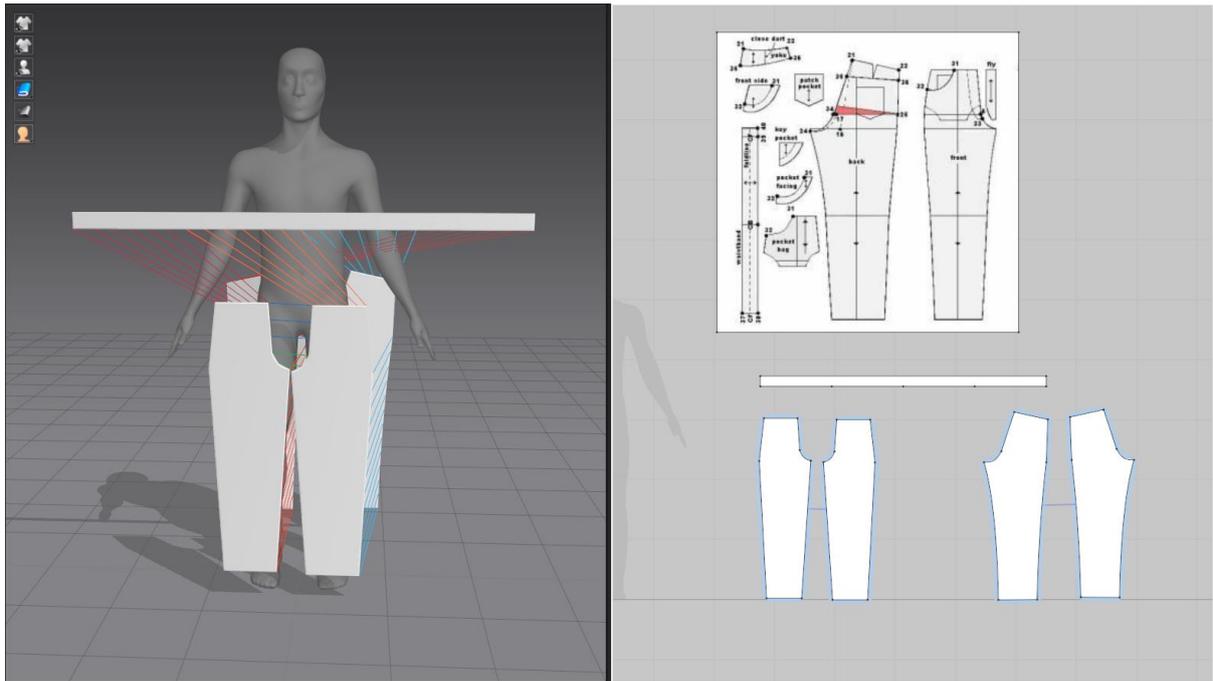


Figure 47. Image of initial stage of Marvelous Designer garment creation.

The trousers were created first using 2D patterns that were measured to the correct length and width in millimetres. These 2D patterns also mimic the same unstitched patterns that would be used in real clothes creation and sewing, each 2D pattern was then placed roughly where it was needed and all of them were then sewed together and the fabric was simulated which allows Marvelous to calculate how the fabric should react based on the shape and material of it and the character mesh that it is being placed onto, the trousers will then be created in 3D and can be manipulated to better fit to the mesh.



*Figure 48. Image of 3D simulated trousers..*

In order to make the appearance of the trousers fit with the intended realistic aesthetic I needed to add pockets to the front and back as well as belt loops and the front part of jeans that houses the zipper.

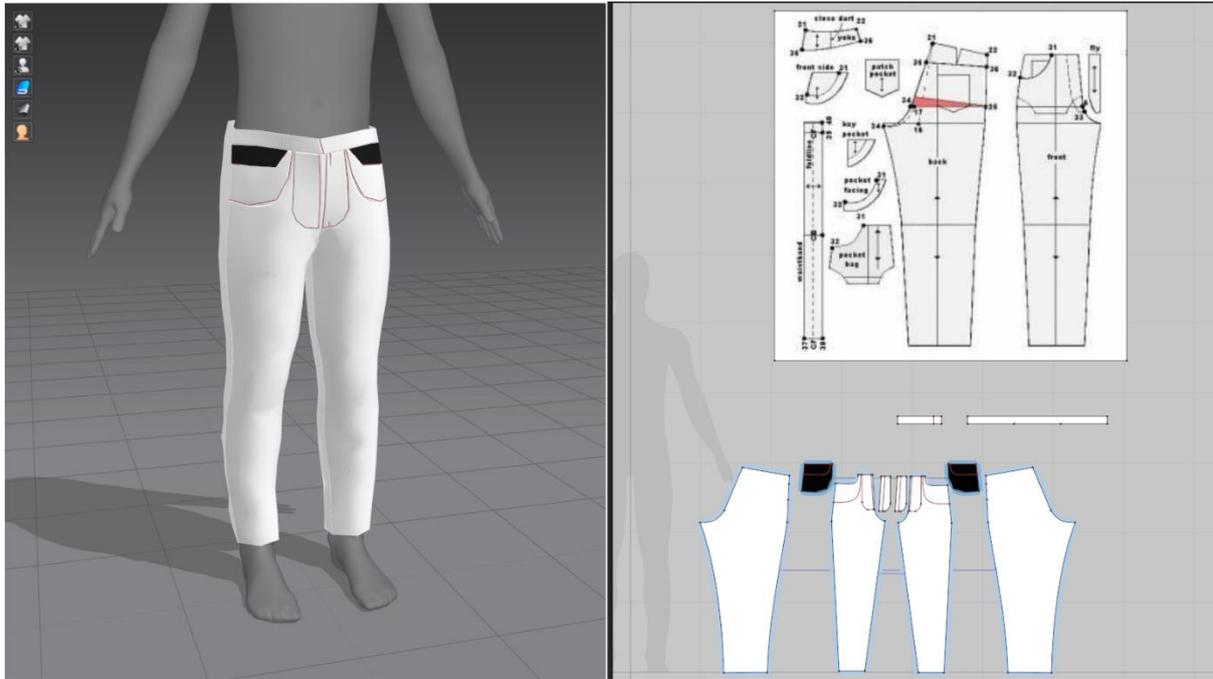


Figure 49. Image of trousers garment after adding more detail.

The details that are added to the jeans will be used as normal maps when it comes to the texturing stage, these normal maps will allow for the appearance of raised geometry even though it will only be a texture saving on poly count and providing better performance than if geometry was used. The jeans were the most complicated of the clothing to get right, this is why I focussed on getting them created first before the rest of the clothes, this was also because the rest of the character's clothing was going to be over the jeans and with cloth simulation it is easier to build up the clothing in the order that it is required to appear in.



*Figure 50. Image of the back of the garment after adding more detail.*

The next stage of the clothing development was to create the t-shirt that can be seen underneath the hoodie and coat.

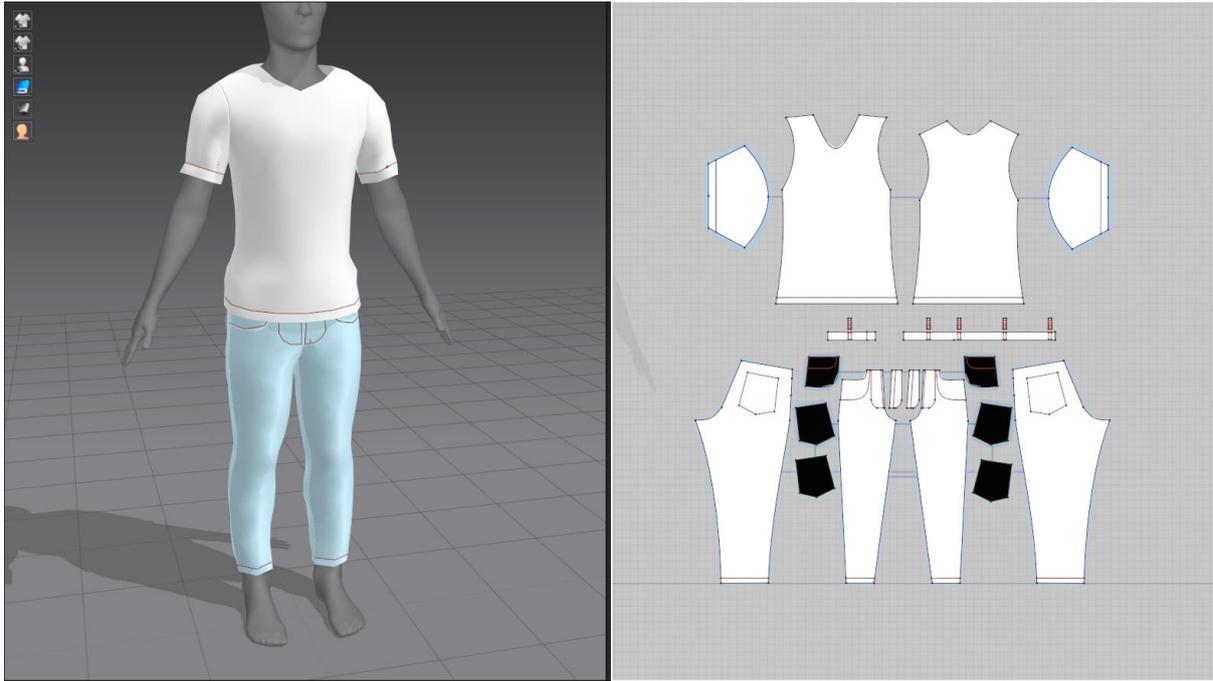


Figure 51. Image of the t-shirt garment.

The t-shirt was much simpler to create as there were no accessories such as pockets and belt loops and the shape of the 2D patterns required were simpler to create and stitch. The t-shirt was stitched and simulated over the trousers while the trousers were frozen so that they would not be simulated and would not move from the position that they were previously manoeuvred into. After the t-shirt had been created and simulated it was duplicated and used as a base to create the hoodie. I lengthened the arms to be long sleeves instead of short ones and added pockets to the front of it. The pattern that made up the front of the torso was sliced in half and a zipper was added to either side to follow the concept art.

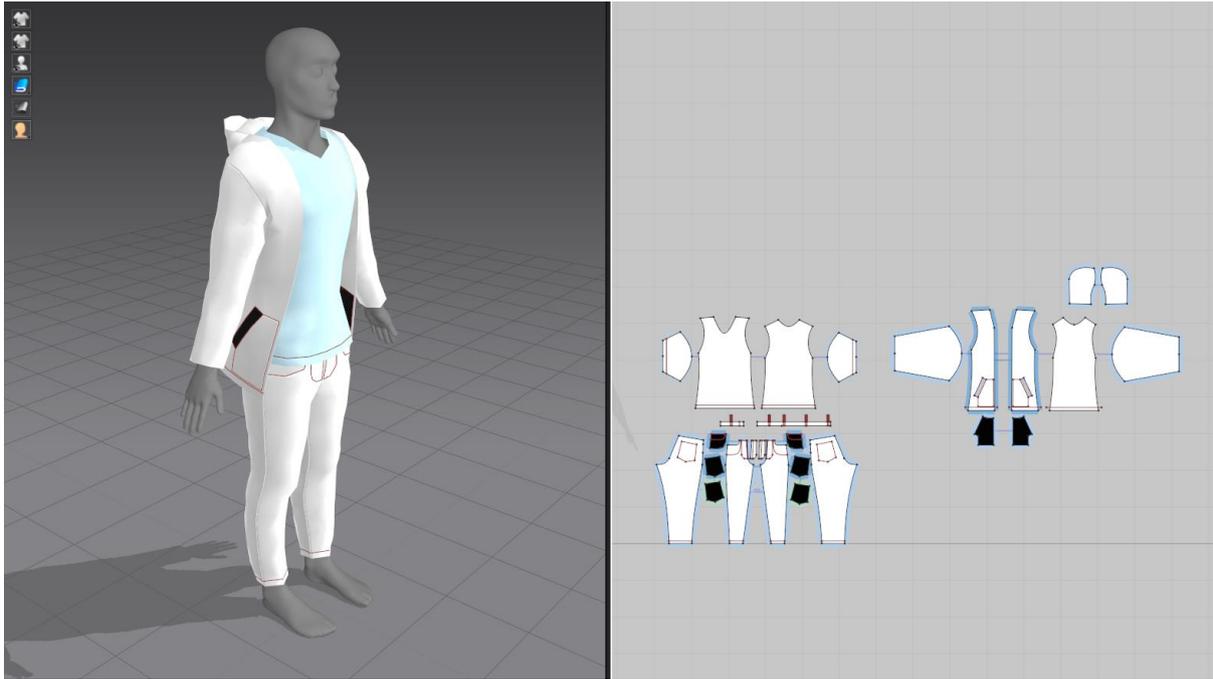
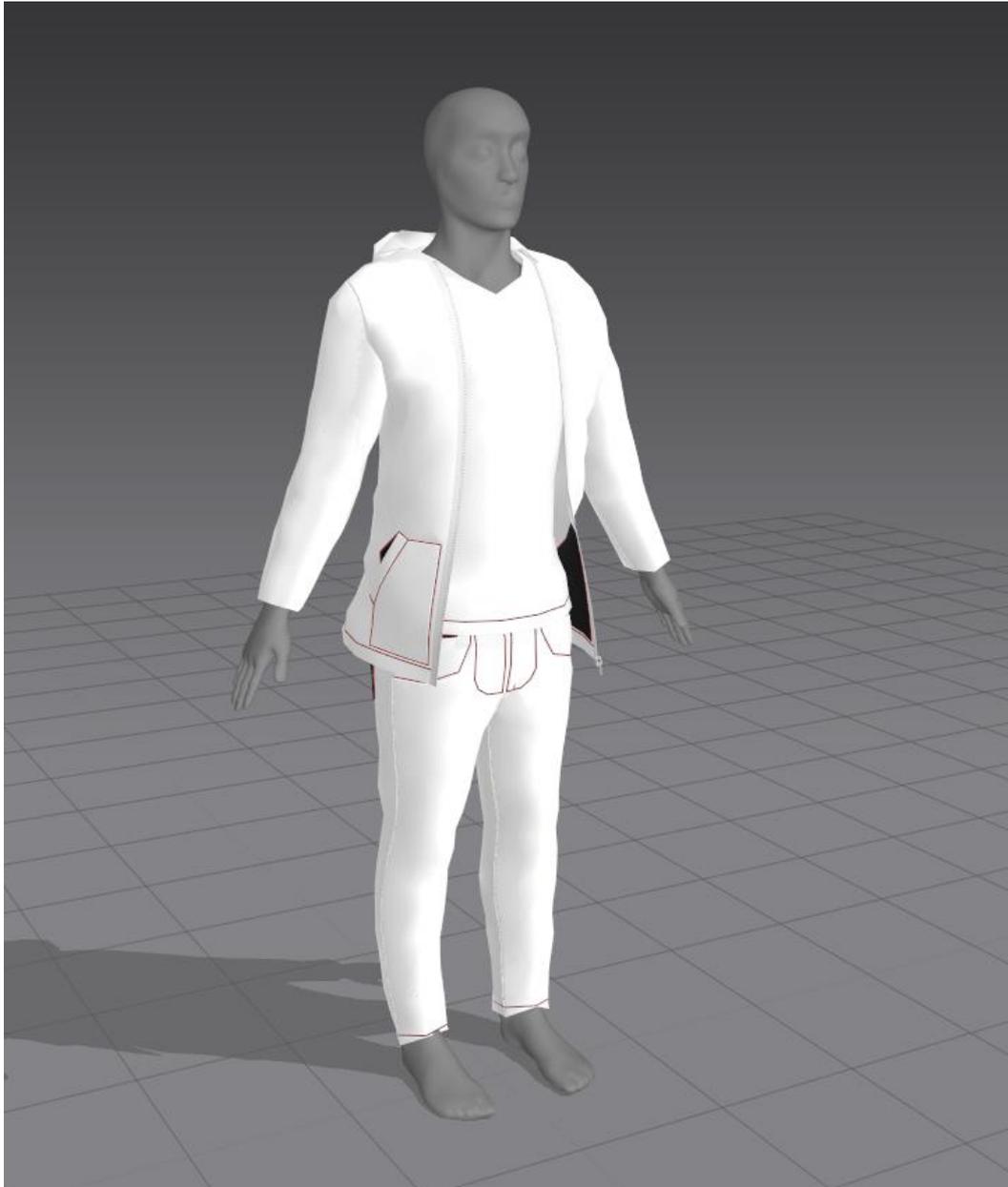


Figure 52. Image of the hoodie garment.

To complete the look of the hoodie a hood was connected to the top of the back-torso pattern. The final piece of clothing that required development in Marvelous Designer was the coat, the base mesh of it being duplicated from the hoodie.



*Figure 53. Image of the completed garments before adding the coat.*

The hood was removed on the mesh that was being utilized as the coat and the pockets on the front were modified to be more inside the coat to reflect how they look on a similar coat in reality.



Figure 54. Image of a coat reference that I was using for the design I was implementing. Can be found at <https://www.fanjackets.com/product/long-grey-wool-coat-mens/>.

The coat was also made slightly larger in order to fit over the clothes underneath it and a larger collar and lapel pattern were added to reflect the reference image.

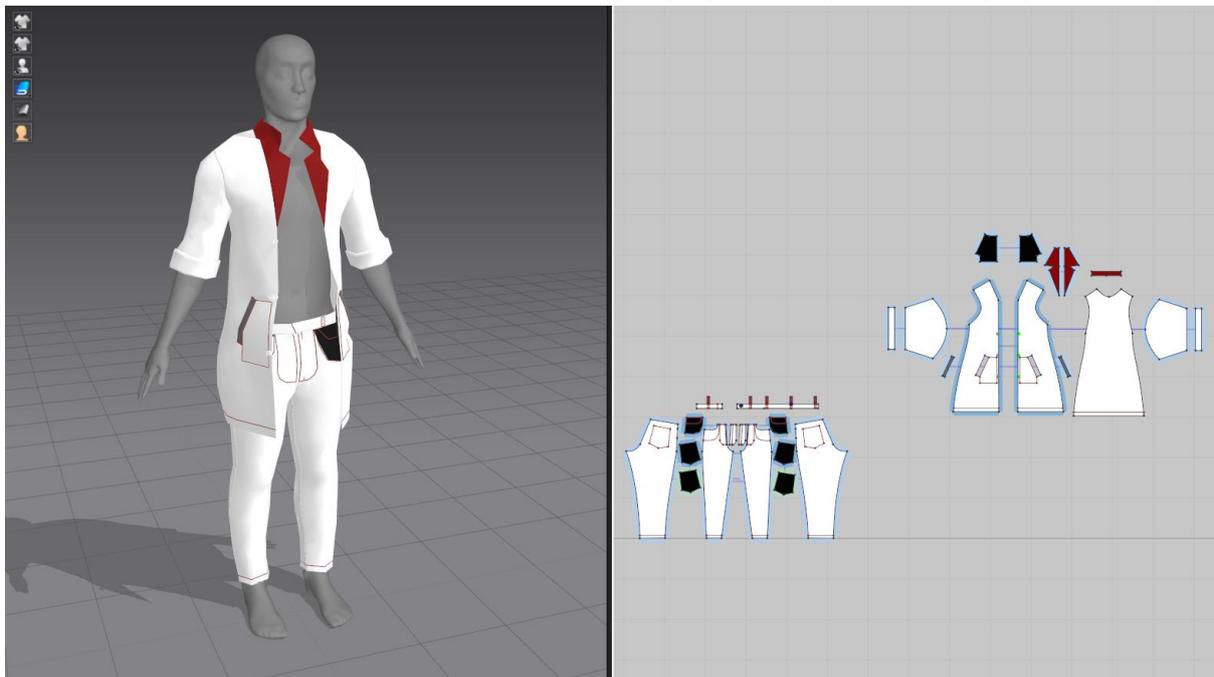


Figure 55. Image of the completed coat garment.

The zipper at the front was removed and replaced with buttons instead. Some part of the coat and rest of the clothing I was planning on fixing in ZBrush after the cloth simulation in Marvelous had been completed, as well as the creation of the shoes.

## SELF-ASSESSMENT OF LEARNING

The outcome of the project was overall unsuccessful due to the circumstances that presented themselves two months before the project's completion. Before the project's suspension I was required to change the gantt chart in order to complete the project and was on track with the revised gantt chart and to finishing the project on time. To improve this project I would continue with development until the project's completion. With each sculpt that I have done I have improved upon the last one and this project was no exception to this. However, I believe that my biggest learning outcome from this project was the exploration and development of realistic hair, created with planes.

## REFERENCES

### DEVELOPMENT PROCESS AND PIPELINE

- Karon, P., 2016. *Introduction to Game Asset Creation: Learning Flow Overview* [online]. CG Cookie. Available from: <https://cgcookie.com/articles/from-concept-to-game-introduction-to-game-asset-creation> [Accessed 16 Feb 2020].
- Petit, N., 2015. *Asset Workflow for Game Art: 3D Modeling | Treehouse Blog* [online]. Treehouse Blog. Available from: <https://blog.teamtreehouse.com/asset-workflow-game-art-3d-modeling> [Accessed 16 Feb 2020].
- Stefyn, N., 2019. *How Video Games Are Made: The Game Development Process* [online]. Cgspectrum.com. Available from: <https://www.cgspectrum.com/blog/game-development-process> [Accessed 16 Feb 2020].
- Kean, M., 2013. *Pluralsight* [online]. App.pluralsight.com. Available from: <https://app.pluralsight.com/course-player?clipId=5b9eb80b-1b04-4bb4-86ba-454387026bbc> [Accessed 16 Feb 2020].
- Terävä, T., 2017. *Workflows for creating 3D game characters* [online]. Theseus.fi. Available from: [https://www.theseus.fi/bitstream/handle/10024/131241/Terava\\_Tapio.pdf?sequence=1&isAllowed=y](https://www.theseus.fi/bitstream/handle/10024/131241/Terava_Tapio.pdf?sequence=1&isAllowed=y) [Accessed 21 May 2020].
- Lampel, J., 2017. *Normal vs. Displacement Mapping & Why Games Use Normals* [online]. CG Cookie. Available from: <https://cgcookie.com/articles/normal-vs-displacement-mapping-why-games-use-normals?page=2> [Accessed 18 Feb 2020].

- Anon., 2020. *Unreal Engine 5 Revealed! | Next-Gen Real-Time Demo Running on PlayStation 5* [online]. Youtube. Available from: <https://www.youtube.com/watch?v=qC5KtatMcUw&t=148s> [Accessed 28 May 2020].

## CONCEPT ART AND CYBERPUNK LORE

- Kegg, D., 2018. *Pluralsight* [online]. Pluralsight. Available from: <https://app.pluralsight.com/course-player?clipId=8ef17bc1-150d-473e-a48c-4b7eec55cf1a> [Accessed 7 Dec 2019].
- Anon., 2020. *Netrunner* [online]. Cyberpunk Wiki. Available from: <https://cyberpunk.fandom.com/wiki/Netrunner> [Accessed 16 Feb 2020].
- Anon., 2020. *The Net* [online]. Cyberpunk Wiki. Available from: [https://cyberpunk.fandom.com/wiki/The\\_Net](https://cyberpunk.fandom.com/wiki/The_Net) [Accessed 16 Feb 2020].
- Anon., 2020. *Cyberlimbs* [online]. Cyberpunk Wiki. Available from: <https://cyberpunk.fandom.com/wiki/Cyberlimbs> [Accessed 16 Feb 2020].
- Anon., 2020. *Cyberware in Cyberpunk 2020* [online]. Cyberpunk Wiki. Available from: [https://cyberpunk.fandom.com/wiki/Cyberware\\_in\\_Cyberpunk\\_2020](https://cyberpunk.fandom.com/wiki/Cyberware_in_Cyberpunk_2020) [Accessed 16 Feb 2020].
- Floyd, D., 2018. *Tracer & Pose Design 101 - The Animation of Overwatch* [online]. Youtube. Available from: <https://www.youtube.com/watch?v=1EJSAm6OFOs> [Accessed 16 Feb 2020].

## JAPANESE ANIMAL FOLKLORE AND MEANINGS

- Anon., 2019. *Japanese Symbolic Animals and What They Mean | Japanese Shop* [online]. The Japanese Shop Blog. Available from: <https://www.thejapaneseshop.co.uk/blog/japanese-symbolic-animals-meanings/> [Accessed 29 Jan 2020].
- Homer, C., 2018. *Japanese animals | symbolism & culture* [online]. Travellocal.com. Available from: <https://www.travellocal.com/inspiration/blog/1065/japan-animal-symbolism> [Accessed 29 Jan 2020].
- Anon., 2020. *Animals in Japanese Folklore* [online]. Nga.gov. Available from: <https://www.nga.gov/features/life-of-animals-in-japanese-art.html> [Accessed 29 Jan 2020].

## COLOUR THEORY AND MEANING

- Anon., 2019. *Color Meaning and Psychology – graf1x.com* [online]. Graf1x.com. Available from: <https://graf1x.com/color-psychology-emotion-meaning-poster/> [Accessed 29 Jan 2020].
- Anon., 2018. *Meaning of Colors in Color Psychology* [online]. Empowered By Color. Available from: <https://www.empower-yourself-with-color-psychology.com/meaning-of-colors.html> [Accessed 29 Jan 2020].
- Olesen, J., 2020. *Color Meanings - All About Colors and Symbolism* [online]. Color-Meanings.com. Available from: <https://www.color-meanings.com/> [Accessed 29 Jan 2020].
- Anon., 2020. *How to use a colour wheel* [online]. Dulux.com.au. Available from: <https://www.dulux.com.au/how-to/how-to-use-colour/how-to-use-a-colour-wheel> [Accessed 30 Jan 2020].

## 3D CHARACTER CREATION

- Nagulov, D., 2015. *Anatomy For 3D Artists: The Essential Guide For CG Professionals*. Worcester: 3DTotal Publishing.
- Anon., 2020. *Pin by 晶 孙 on 二次元 (With images)* [online]. Pinterest. Available from: <https://www.pinterest.co.uk/pin/652599802236232797/?d=t&mt=login> [Accessed 21 Feb 2020].

- Chopra, N., 2020. *3D Character Modelling | 2017 | Maya* [online]. Nitish Chopra. Available from: <https://nitishchopra.com/portfolio/3d-character-modelling/> [Accessed 21 Feb 2020].
- Anon., 2020. *Notion – The all-in-one workspace for your notes, tasks, wikis, and databases.* [online]. Notion. Available from: <https://www.notion.so/Clothes-in-Marvelous-Designer-c4f8c395a0744eef9762c47c04c3d850> [Accessed 22 Feb 2020].
- Thuc Le, R., 2016. *THE MAKING OF RE-IMAGINED ELLIE – THE LAST OF US FANART by Ray Thuc Le - zbrushtuts* [online]. zbrushtuts. Available from: <https://zbrushtuts.com/2016/09/27/the-making-of-re-imagined-ellie/> [Accessed 26 Feb 2020].
- Flipped Normals, 2018. *Reprojecting Details in ZBrush - Top Production Tip* [online]. Youtube. Available from: <https://www.youtube.com/watch?v=Zp07GW3rND0> [Accessed 28 Feb 2020].
- Anon., 2018. *UV Mapping Game Characters in Maya - Unity Learn* [online]. Unity Learn. Available from: <https://learn.unity.com/project/uv-mapping-game-characters-in-maya> [Accessed 1 Mar 2020].
- My Oh Maya, 2017. *Maya 2017: Quick Rig* [online]. Youtube. Available from: <https://www.youtube.com/watch?v=o1L3Unmm588> [Accessed 1 Mar 2020].
- Rigging Dojo, 2019. *Learn: Maya HIK Custom Rig Motion Capture Retargeting and Animation in 1 minute - Rigging Dojo* [online]. Rigging Dojo. Available from: <https://www.riggingdojo.com/2019/02/08/learn-maya-hik-custom-rig-motion-capture-retargeting-and-animation-in-1-minute/> [Accessed 2 Mar 2020].
- Autodesk Forums, 2017. *Painting skin weight tips* [online]. Forums.autodesk.com. Available from: <https://forums.autodesk.com/t5/maya-animation-and-rigging/painting-skin-weight-tips/td-p/7370689> [Accessed 3 Mar 2020].
- Williams, R., 2008. *Richard Williams animation masterclass presents the animator's survival kit animated.* [S.l.]: Faber.
- Anon., 2020. *Maya Character Animation Tips* [online]. Cgsociety.org. Available from: <https://cgsociety.org/news/article/3463/maya-character-animation-tips> [Accessed 4 Mar 2020].
- JohnDiCamillo, 2016. *How can I make a material look soft - Unreal Engine Forums* [online]. Unreal Engine Forums. Available from: <https://forums.unrealengine.com/development-discussion/content-creation/84370-how-can-i-make-a-material-look-soft> [Accessed 5 Mar 2020].
- Anon., 2020. *State Machines* [online]. Docs.unrealengine.com. Available from: <https://docs.unrealengine.com/en-US/Engine/Animation/StateMachines/index.html> [Accessed 6 Mar 2020].

## 3D HAIR CREATION

- YouTube. (2017). *Modeling hair for games.* [online] Available at: <https://www.youtube.com/watch?v=rqkSebnRhZE> [Accessed 14 Nov. 2019].
- McDermott, W. (2013). *Creating Polygon Hair for Game Characters.* [online] YouTube. Available at: <https://www.youtube.com/watch?v=6Wi4-fdeYyM> [Accessed 14 Nov. 2019].
- Lithvall, J. (2018). *Webinar Replay | Creating Hair for Games | Johan Lithvall.* [online] YouTube. Available at: <https://www.youtube.com/watch?v=Z58OQ9x0E68> [Accessed 14 Nov. 2019].
- MonkeySuite. (2018). *Hair tutorial Part 5.* [online] Available at: <https://www.youtube.com/watch?v=4Uu2O2AEO5c> [Accessed 14 Nov. 2019].
- Roselle, S. (2016). *XGen for Game Character Hair (Part 1).* [online] YouTube. Available at: [https://www.youtube.com/watch?v=1Fs6rle\\_lbE](https://www.youtube.com/watch?v=1Fs6rle_lbE) [Accessed 14 Nov. 2019].
- CGLYO. (2018). *CGLYO - Realistic Ponytail HairStyle with XGen & Redshift - Part01.* [online] Available at: <https://www.youtube.com/watch?v=c2ZEYCLKOZk> [Accessed 18 Nov. 2019].
- Kollar, A. (2019). *Man of Medan - Julia.* [online] ArtStation. Available at: <https://www.artstation.com/artwork/Qzqq1B> [Accessed 5 Dec. 2019].
- Lovell, S. (2019). *Man of Medan - Conrad.* [online] ArtStation. Available at: <https://www.artstation.com/artwork/6aGDGx> [Accessed 5 Dec. 2019].

- Naughty Dog., 2016. *Making of Uncharted 4 Nathan Drake (With images) | Nathan drake, Digital artists, Drake* [online]. Pinterest. Available from: <https://in.pinterest.com/pin/575194183633186487/> [Accessed 10 Dec 2019].

## APPENDICES

### MALE CHARACTER MOODBOARD

- Cornet, C. (2015). *Cyberpunk male character*. [online] ArtStation. Available at: <https://www.artstation.com/artwork/xZPWO> [Accessed 14 Nov. 2019].
- Creativeuncut.com. (2019). *Errorist Male Art - Remember Me Art Gallery*. [online] Available at: <https://www.creativeuncut.com/gallery-22/rm-errorist-male.html> [Accessed 14 Nov. 2019].
- Lim, M. (2015). *Character*. [online] ArtStation. Available at: <https://www.artstation.com/artwork/character-77d86b3d-cb07-4523-b71f-6717abd2945d> [Accessed 14 Nov. 2019].
- veganrecipe. (n.d.). *Cyberpunk 2077 Cyborg #cyberpunk*. [online] Available at: <http://veganrecipe.sosyalmanya.com/image.php?id=193487> [Accessed 14 Nov. 2019].
- Krauel, L. (n.d.). *iphone ios 7 wallpaper tumblr for ipad | Robot concept art, Concept art, Cyberpunk character*. [online] Pinterest. Available at: <https://www.pinterest.co.uk/pin/21532904446190541> [Accessed 14 Nov. 2019].
- Instagram. (2019). *FUBAR props on Instagram: "Don't know about you, but I really love the retro wave aesthetics. So just had to edit this photo for that extra touch. Photo by..."*. [online] Available at: [https://www.instagram.com/p/BwWoqT\\_jSUr/](https://www.instagram.com/p/BwWoqT_jSUr/) [Accessed 14 Nov. 2019].
- Forums - Cubebrush. (2018). *Cyberpunk 2077 - Fan Art*. [online] Available at: <https://forums.cubebrush.co/t/cyberpunk-2077-fan-art/5985> [Accessed 14 Nov. 2019].
- Fado, J. (2019). *Neon alley*. [online] ArtStation. Available at: <https://www.artstation.com/artwork/N5eXK5> [Accessed 14 Nov. 2019].
- Instagram. (2019). *FΣB on Instagram: "By Ahmet Atil Akar - @ahmetatilakar #killer #katana #sword #efes #belt #drone #hightech #head #neck #urban #street #streetstyle #tower..."*. [online] Available at: [https://www.instagram.com/p/BtTtSF\\_IL3a/](https://www.instagram.com/p/BtTtSF_IL3a/) [Accessed 14 Nov. 2019].
- Malese, B. (2019). *"It's not the end of the world, but you can see it from here..."*. [online] Tumblr. Available at: <https://cybernetic-psychosis.tumblr.com/image/163462318852> [Accessed 14 Nov. 2019].
- Streetsamurai.tumblr.com. (2018). *Tumblr*. [online] Available at: <https://streetsamurai.tumblr.com/post/172613592855/damascusapparel-let-us-gather-strength-as-we> [Accessed 14 Nov. 2019].
- Pinterest. (2019). *sink00 art in 2019 | Cyberpunk character, Futuristic armour, Armor concept*. [online] Available at: <https://www.pinterest.co.uk/pin/822681056911865929> [Accessed 14 Nov. 2019].
- Zhao, W. (2019). *Pin by whinnny zhao on sci-fi in 2019 | Cyberpunk fashion, Cool costumes, Cyberpunk character*. [online] Pinterest. Available at: <https://www.pinterest.co.uk/pin/480829697711240225> [Accessed 14 Nov. 2019].
- Pinterest. (n.d.). *Pin by Streetwear Fashion Trends By Edwin Vonholy / Fashion Outfits on Featured Fashion Trends | Character design inspiration, Character design, Character art*. [online] Available at: <https://www.pinterest.co.uk/pin/804174077197102389> [Accessed 14 Nov. 2019].

### FEMALE CHARACTER MOODBOARD

- veganrecipe. (n.d.). *I'm In Love With This #cyberpunk*. [online] Available at: <http://veganrecipe.sosyalmanya.com/image.php?id=193488> [Accessed 14 Nov. 2019].
- veganrecipe. (n.d.). *ArtStation - Ciri Cyberpunk 2077, Bartek Wąsacz #cyberpunk*. [online] Available at: <http://veganrecipe.sosyalmanya.com/image.php?id=193490> [Accessed 14 Nov. 2019].
- veganrecipe. (n.d.). *Cyberpunk, Girl, Sci-Fi, 4K,3840x2160, Wallpaper #cyberpunk*. [online] Available at: <http://veganrecipe.sosyalmanya.com/image.php?id=193497> [Accessed 14 Nov. 2019].
- Cgsociety.org. (2018). *rx135 — DASH-*. [online] Available at: <https://cgsociety.org/c/featured/58f2/dash> [Accessed 14 Nov. 2019].
- Skeor, T. (2019). *Coup de Coeur : les superbes digital work de l'artiste Tony Skeor | Technology Online*. [online] Technologyonline.space. Available at: <https://www.technologyonline.space/coup-de-coeur-les-superbes-digital-paintings-de-lartiste-tony-skeor/> [Accessed 14 Nov. 2019].
- Pinterest. (n.d.). *style Cyberpunk Fashion | Cyberpunk art, Cyberpunk girl, Cyberpunk aesthetic*. [online] Available at: <https://www.pinterest.co.uk/pin/4433299621912383> [Accessed 14 Nov. 2019].
- Royaltyphotographyjournal.chicloth.ru. (n.d.). *Photography Ideas City Lights 70+ Ideas*. [online] Available at: <http://royaltyphotographyjournal.chicloth.ru/360113-photography-ideas-city-lights-39-ideas.html> [Accessed 18 Nov. 2019].
- Woinski, O. (2019). *Neon #Study #by #Oskar #Woinski - My Draw Blog*. [online] My Draw Blog. Available at: <http://www.draw.fashiondesignn.com/neon-study-by-oskar-woinski/> [Accessed 18 Nov. 2019].
- Pinterest. (2019). *A Thousand Years – Scandroid. Single releases July 14. Artwork by Ninja Jo | Fantasy concept art, Cyberpunk character, Cyberpunk art*. [online] Available at: <https://www.pinterest.co.uk/pin/703898616743563354> [Accessed 26 Nov. 2019].
- Pinterest. (2019). *#SteamMexico #ElRafaSTMX : Comunidad Steam Mexico - www.steammexico.mx in 2019 | Cyberpunk character, Cyberpunk girl, Cyberpunk art*. [online] Available at: <https://www.pinterest.co.uk/pin/605030531170494405> [Accessed 26 Nov. 2019].
- Pinterest. (n.d.). *# cyberpunk, robot girl, cyborg, futuristic, android, sci-fi, science fiction, cyber girl, digital art | Robot girl, Cyberpunk, Sci fi art*. [online] Available at: <https://www.pinterest.co.uk/pin/242420392417366424> [Accessed 26 Nov. 2019].
- Pinterest. (2019). */Cyberpunk City in 2019 | Cyberpunk aesthetic, Cyberpunk, Shadowrun*. [online] Available at: <https://www.pinterest.co.uk/pin/597571444289019470> [Accessed 26 Nov. 2019].
- Pinterest. (2018). *. d o 📷 P O R T S depth obsessed portraits dof | bokeh | hue | motion ..... artist 🎨:... in 2019 | Cyberpunk fashion, Cyberpunk aesthetic, Neon noir*. [online] Available at: <https://www.pinterest.co.uk/pin/549931804496112459> [Accessed 26 Nov. 2019].
- Pinterest. (n.d.). *style Cyberpunk Fashion in 2019 | Cyberpunk art, Cyberpunk fashion, Cyberpunk girl*. [online] Available at: <https://www.pinterest.co.uk/pin/4433299621912379> [Accessed 26 Nov. 2019].
- Pinterest. (n.d.). *style Cyberpunk Fashion in 2019 | Cyberpunk girl, Cyberpunk art, Cyberpunk character*. [online] Available at: <https://www.pinterest.co.uk/pin/4433299621912378> [Accessed 26 Nov. 2019].
- Pinterest. (n.d.). *The Girl With The Owl Tattoo iPhone Wallpaper - iPhone Wallpapers in 2019 | Portrait, Portrait photography, Iphone wallpaper*. [online] Available at: <https://www.pinterest.co.uk/pin/767723067711894584> [Accessed 26 Nov. 2019].
- Pinterest. (2019). *Pin by Shai Daniel on My Cyberpunk work in 2019 | Cyberpunk girl, Cyberpunk art, Cyberpunk character*. [online] Available at: <https://www.pinterest.co.uk/pin/452330356323719723> [Accessed 26 Nov. 2019].

- Pinterest. (2019). *RECLAIMER by Chad Walker » We're funded, but Kickstarter United needs a signal boost — Kickstarter in 2019 | Cyberpunk character, Cyberpunk girl, Cyberpunk art.* [online] Available at: <https://www.pinterest.co.uk/pin/745205069575992468> [Accessed 26 Nov. 2019].
- Irawan, H. (2018). *Character Design and Style Exploration 16.* [online] ArtStation. Available at: <https://www.artstation.com/artwork/qa3Gn> [Accessed 28 Nov. 2019].
- Paolilli, M. (2017). *On Patrol.* [online] ArtStation. Available at: <https://www.artstation.com/artwork/DVGGn> [Accessed 28 Nov. 2019].
- Lloyd, J. (2016). *Tumblr.* [online] Runtheshadows.tumblr.com. Available at: <https://runtheshadows.tumblr.com/post/137806537931/superheroesincolor-blades-daughter-by> [Accessed 28 Nov. 2019].
- DeviantArt. (2019). *Pirowitch Cosmis. by hybridgothica on DeviantArt.* [online] Available at: <https://www.deviantart.com/hybridgothica/art/Pirowitch-Cosmis-395448911> [Accessed 28 Nov. 2019].
- Mullins, J. (2019). *digital art #women #blonde #futuristic #tattoo #robot science fiction Pavel Bondarenko Cyberpunk 2077 #profile #lights #1080P #wallp... in 2019 | Cyberpunk girl, Cyberpunk aesthetic, Cyberpunk fashion.* [online] Pinterest. Available at: <https://www.pinterest.co.uk/pin/743938432179479572/> [Accessed 28 Nov. 2019].
- Bond, P. (2019). *cyberpunk.* [online] ArtStation. Available at: <https://www.artstation.com/artwork/ba3Xog> [Accessed 28 Nov. 2019].
- ArtStation. (2016). *菲律宾.* [online] Available at: <https://www.artstation.com/artwork/vRNea> [Accessed 28 Nov. 2019].
- ArtStation. (2016). *Alissa.* [online] Available at: <https://www.artstation.com/artwork/nbwEr> [Accessed 28 Nov. 2019].
- Ye, S. (2018). *20170214.* [online] ArtStation. Available at: <https://www.artstation.com/artwork/eYKXJ> [Accessed 28 Nov. 2019].
- Instagram. (2019). *C Y B E R P U N K / \ A R T on Instagram: "by DC Chris(artist by artstation). . . #characters #practice #exmachine #mecha #mech #future #futuristic #fantastico #robotics #armor #arm...".* [online] Available at: [https://www.instagram.com/p/BtQYr14l6zX/?utm\\_source=ig\\_share\\_sheet&igshid=1gxdnmr142y01](https://www.instagram.com/p/BtQYr14l6zX/?utm_source=ig_share_sheet&igshid=1gxdnmr142y01) [Accessed 28 Nov. 2019].

## REFERENCE AND HUMAN ANATOMY DIAGRAMS

- McPherson, K., 2020. *Free Diagrams Human Body | human anatomy is the study of structure of human body | Human body anatomy, Human body muscles, Human anatomy, physiology* [online]. Pinterest. Available from: <https://www.pinterest.co.uk/pin/524950900286203728/> [Accessed 4 Feb 2020].
- Mitrofan, B., 2020. *Pin by Bogdan Mitrofan on Therapy | Human body diagram, Human anatomy chart, Human body anatomy* [online]. Pinterest. Available from: <https://www.pinterest.co.uk/pin/844354630114335904/> [Accessed 4 Feb 2020].
- Blue Tree Publishing, 2017. *Skeletal and Muscles Front Large Poster* [online]. Blue Tree Publishing. Available from: <https://www.bluetreepublishing.com/print/133-skeletal-and-muscles-front-large-poster.html> [Accessed 4 Feb 2020].
- Encyclopedia Britannica, 2020. *human skeleton | Parts, Functions, Diagram, & Facts* [online]. Encyclopedia Britannica. Available from: <https://www.britannica.com/science/human-skeleton> [Accessed 4 Feb 2020].
- Jarrett, P., 2020. *Mr Paul Jarrett | Hand and Wrist Anatomy | Murdoch Orthopaedic Clinic* [online]. Murdoch Orthopaedic Clinic. Available from: <https://murdochorthopaedic.com.au/our-surgeons/paul-jarrett/patient-information-guides/hand-wrist-anatomy/> [Accessed 27 Feb 2020].

- Sammut, L., 2020. *Pin by luke sammut on BODY PARTS | Human anatomy and physiology, Medical anatomy* [online]. Pinterest. Available from: <https://www.pinterest.co.uk/pin/488007309604329146/> [Accessed 27 Feb 2020].
- Blue Tree Publishing, 2020. *Hand and Wrist Regular Poster* [online]. Blue Tree Publishing. Available from: <https://www.bluetreepublishing.com/print/97-hand-and-wrist-regular-poster.html> [Accessed 27 Feb 2020].
- Littlejohn, A., 2020. *Dupuytren's Recurrence flexor muscles and Tendons of left Hand | Hand therapy, Human anatomy and physiology, Anatomy and physiology* [online]. Pinterest. Available from: <https://www.pinterest.co.uk/pin/572449802618645329/> [Accessed 27 Feb 2020].
- Fan Jackets, 2020. *Martin Mens Long Grey Wool Coat* [online]. Fan Jackets. Available from: <https://www.fanjackets.com/product/long-grey-wool-coat-mens/> [Accessed 10 Mar 2020].