DEGREE PROJECT

Optimizing topology for a game Character

Creating a humanoid game character for animation

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Preface

This thesis summarizes my bachelor's degree in Computer Graphics at Luleå University of Technology in Skellefteå, Sweden.

I would like to thank my classmates for these three years of studies and fun, I would also like to thank LTU and my instructors Arash Vahdat, Håkan Wallin, Samuel Lundsten, Stefan Berglund, Fredrik Tall and Aron Strömgren for making this education possible.

Måns Mäkinen

Abstract
This thesis will go through how to create good topology for a humanoid character that will be animated for a game.

First, I will go through some things to keep in mind and why they are important. I will then create two different models, one when I’m following the principles i have gone through in the thesis and one when I don’t do that and then compare the results to anatomy references.

The two models will have the same weight paints as far as possible and will play the same animation.

The purpose is to be able to use this thesis as a help with that your supposed to think about when you create your characters topology and how to avoid simple mistakes.

Sammanfattning

Denna rapport kommer gå igenom hur man skapar bra topologi för en humanoid karaktär som ska animeras för ett spel.

Först kommer jag ta upp lite olika saker man ska tänka på och varför det är viktigt. Jag kommer sedan skapa två olika modeller, en när jag mer följer det som jag har gått igenom och en när jag inte gör det och sedan jämföra dem med anatomi referenser.

De två karaktärerna kommer ha så lika weight paints som möjligt och köra samma animation.

Syftet är att man ska kunna ha den här rapporten som hjälp med vad man ska tänka på när man skapar sin karaktärtopologi och hur man kan undvika simpla misstag.

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1 Preamble

1.1 Background

Creating good topology is something that has always been a hard part of being a character artist. There are a lot of things you need to think about when creating your character or prop. How to make the character deformations look like a real person and how to do this on a low polygon budget.

1.2 Problem

A big problem when creating a game character is how to create the topology for the best results when animating. Essentially how to make the character look like a real human when its moving and how to create the illusion of muscles under the skin.

1.3 Question Formulation

What should you think about when creating a game character?

1.4 Purpose

The purpose of this thesis is to show some ways to create good topology for a humanoid video game character centered around animation and mention why this matter, what you should think about. The idea is that this thesis will be a simple guide of some basic guidelines to be used when creating a character.

1.5 Delimitations

The thesis will be limited to just the arms, legs and the body and not head, hands or feet. It will also only focus on human or humanoid characters. Also limited to a quite low polygon budget to easier see the deformations of individual polygons.

2 Theory

2.1 Word list

2.1.1 Topology

Topology is how the layout of the model looks. Where and how all the edges and vertices are placed to create the mesh surface. Good topology is essential if you want good deformation and fast framerates. A bad topology can in some cases create rendering problems.

Mastering creating good topology takes time to learn. It usually requires a lot of trial and error to learn what happens when your topology is bad.[1]

2.1.2 Edge loop & Edgeflow

An edge loop is a series of connected faces or edges that runs completely around an object back to a starting point.[2] Edgeflow are how the edge loops flow on your model.[3]

2.2 Topology

As mentioned in the word list topology is the layout of the polygons the 3d model in build by and how they flow.

A good game topology should center around creating a good silhouette, define edge loops for better deformation, minimize the stretching of textures and the changes between Vertexnormals and make it easy to create good UV-seams. One of the main purpose of a good topology is to define the silhouette of the model, if the polygons don't add to the silhouette don't add them depending on the polygon budget your working after.[4]

When thinking about the deformation of a model a good topology has its vertices and edges in places to give the model a good bending, compression and stretching when the model is skinned or morphed.[5] A good topology maintains it volume when bent and doesn't collapse. [6]

A bad topology generally lack definition and don't have an edgeflow that flows with the model. A good topology has an edgeflow that defines the flow of the model and creates a better shape of the model often with less polygons. It also has anatomy in mind to get the flow and deformations as close to a real human as possible.[7]

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[1] Polycount, (2017), *"Topology"*, Polycount

[2] Wings 3D, (2018), *"Edge Loops"*, Wings 3D

[3] Niko Mäkelä, (2010), *"Surface flow - why it matters"*, CGmascot

[4] Polycount, (2017), *"Topology"*, Polycount

[5] Polycount, (2017), *"Topology"*, Polycount

[6] Polycount, (2017), "*Limb Topology*", Polycount

[7] Niko Mäkelä, (2010), *"Surface flow - why it matters"*, CGmascot

When animating a bad topology, it looks unnatural and deforms in unnatural ways compared to a real human.[8]

2.3 Creating a character

2.3.1 Shoulders

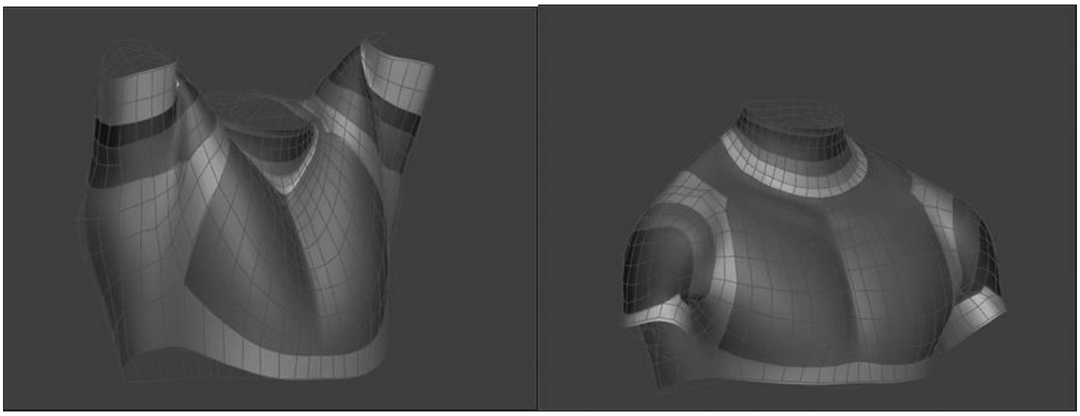

Figure 2.1: Shoulder topology example. (Brian Tindall 2009)

When creating the shoulder geometry there are a lot of things you want to consider with how you structure your edgeflow and where you place your polygons. There are two main problem areas, these are the armpit and over the arm socket. If you don't have enough geometry in the armpit it will stretch when the characters arms are above the head and if you have to much it might deform in a unnatural way when the characters arms are down.

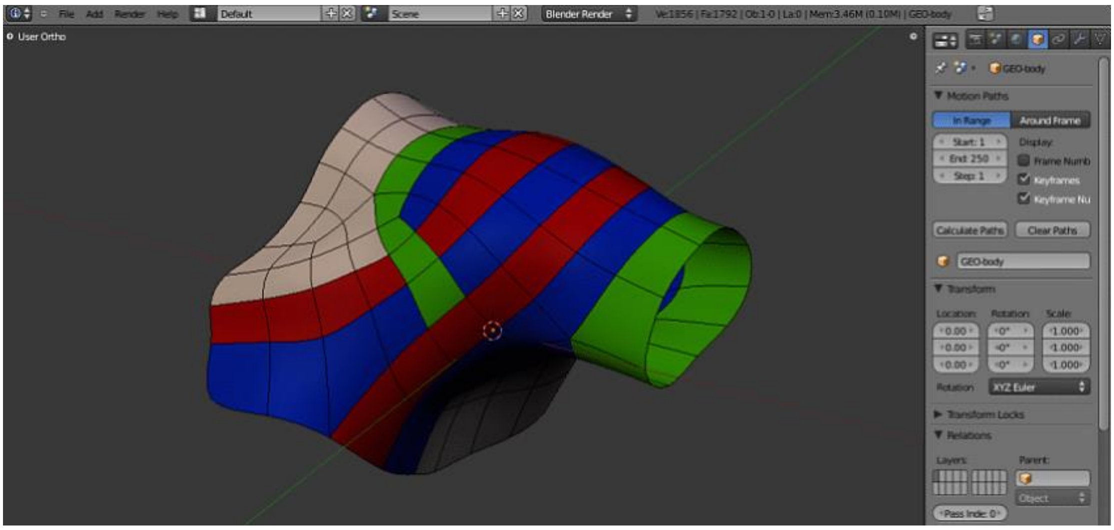

Figure 2.2: Topology review shoulder. (Jonathan Williamson 2010)

The shoulder edge loops should go down on the chest and around the back. To define the shoulder, you need to use some tricky edge loops as the green one in the picture above. This type of loop is called a x-loop. It's two loops going opposite direction forming an x. It helps define the shoulder to create a nice look and work as a great way to attach the arm to the body geometry. [9]

[8] Niko Mäkelä, (2010), *"Surface flow - why it matters"*, CGmascot

[9] Niko Mäkelä, (2010), *"Modeling for animation - Body"*, CGmascot

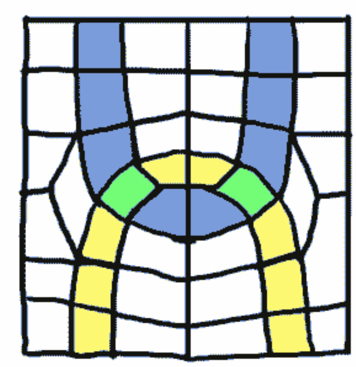

Figure 2.3: diagram of a x-loop. (Niko Mäkelä 2010)

When creating the character especially the shoulders you want to think about which pose you place the character in. To place your character in a T-pose was the standard before but because a character's arm is seldom in the upper half, it now more common to use a relaxed pose also called A-pose. With a A-pose all the limbs are between the two extremes making it easier to rig as it helps the IK solver determine the preferred angle and helps with texture stretching on the shoulders when the arms go down all the way.[10]

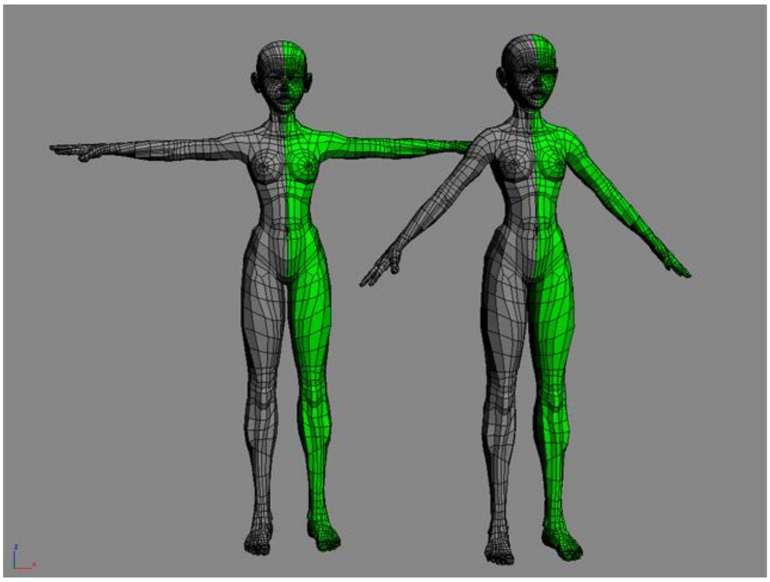

Figure 2.4: T-pose vs A-pose (A. Wiro 2004)

In the image it shows that when in A-pose it's easier to get more subdivisions on the shoulder. More geometry means that each edge doesn't need to move as much when extending creating less stretching.

Some riggers prefer a pose that looks like the character are sitting on a motorcycle to minimize stretching problems in the shoulder area. [11]

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[10] Cineversity, (2018), *"T Pose Wiki"*, Cineversity

[11] Ferdinand Engländer, (2015), "*The T-pose – all about this mighty blueprint*", Animatorisland

2.3.2 Knees and elbows

Knees and elbows work in a similar fashion as each other. They are both quite easy to create and might work with just two edge rings.

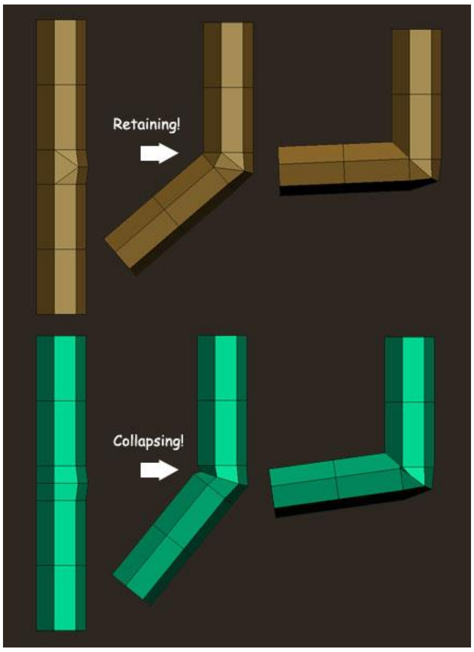

Figure 2.5: Limb topology (Polycount, 2015)

The problem with only using two edge rings as the green cylinder shows is that when bent the hollow of the knee or the armpit might deform improperly and collapse.

A better way is to use two tris instead of just quads, this creates a bigger quad in the hollow of the knee that retains the limbs volume. This is shown on the yellow cylinder in fig 2.5. [12]

[12] Polycount, (2017), "*Limb Topology*", Polycount

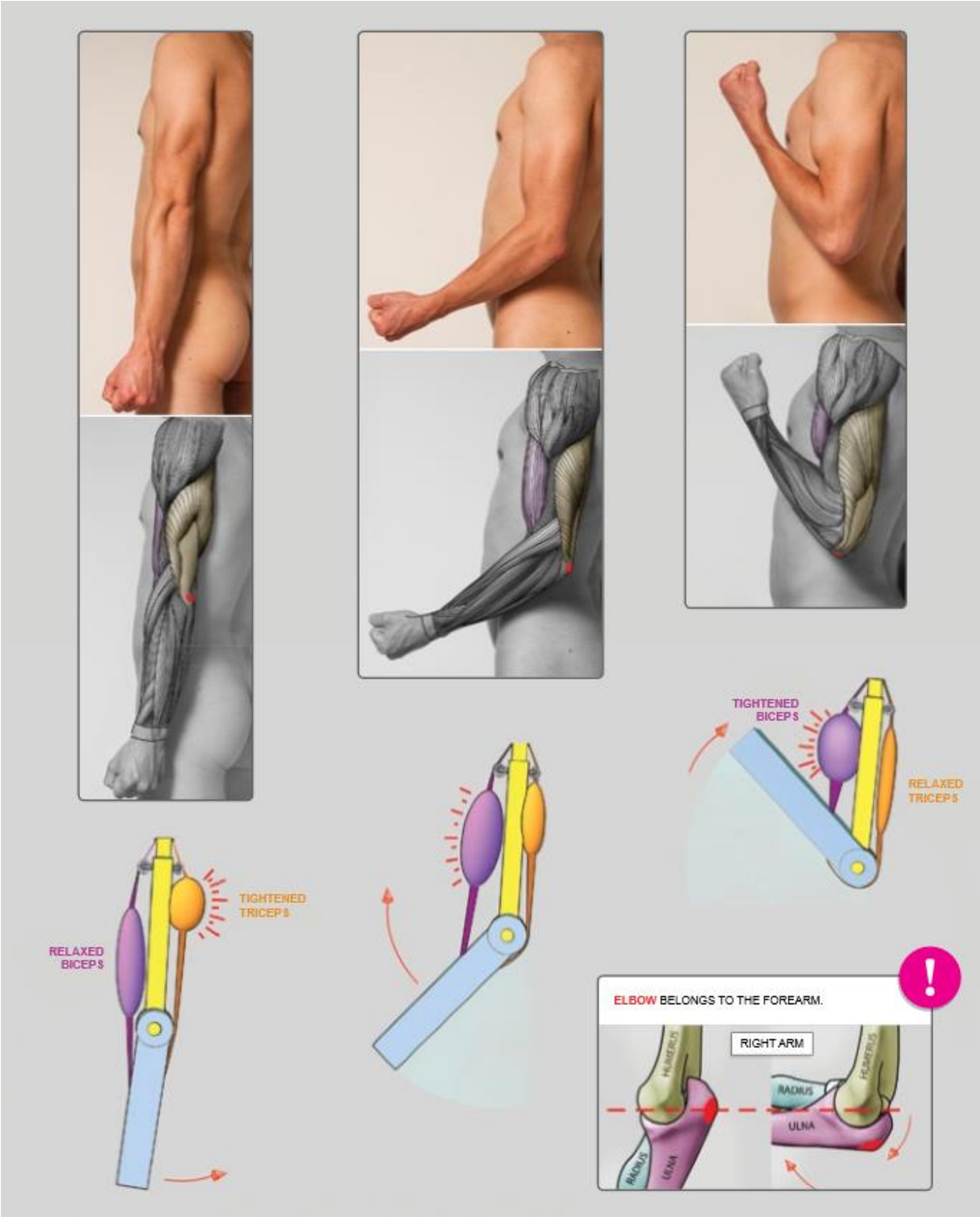

Figure 2.6: arm muscles moving (Uldis Zarins 2014)

When a real arm or leg is moving it's the muscles underneath that tighten and relax as shown in fig 2.6. When creating an arm or leg in 3d we want to have the same effect. This is quite hard to create for a video game character so the important part to consider is that the limbs don't collapse and lose mass.[13]

[13] Polycount (2017) "*Limb Topology*", Polycount

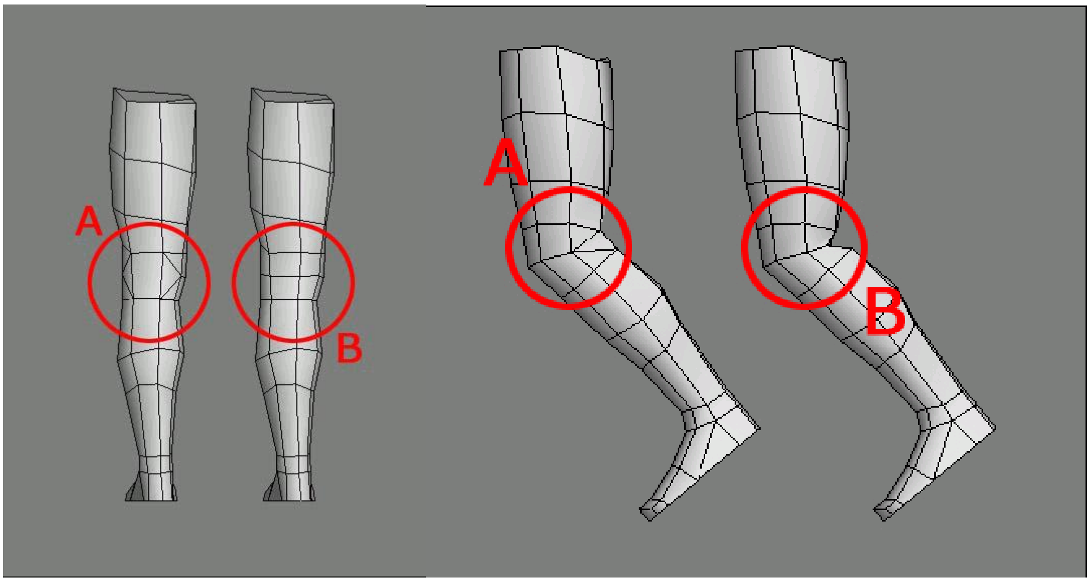

Figure 2.7: Leg topology. (Polycount, 2015)

Figure 2.7 shows a leg created using the same method shown on the cylinders in figure 2.5, it shows quite clearly a collapse of the edge loop on the B-leg. This makes the leg look more natural and move like a real leg.

When defining the kneecap and elbow an x-loop might be useful. The image below shows a knee with an x-loop with much mass left in to define the knee cap. To define the kneecap isn't as much of a trouble area as it doesn't deform as much as the hollow of the knee.[14]

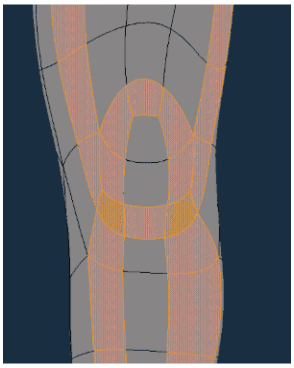
Figure 2.8: Knee with x-loop (Niko Mäkelä 2010)

2.3.3 Body

The body is mainly how to connect all the other topologies of the character. There are some things that you want to consider when creating the body.

[14] Niko Mäkelä (2010) - "*Modeling for animation - Body*", CGmascot

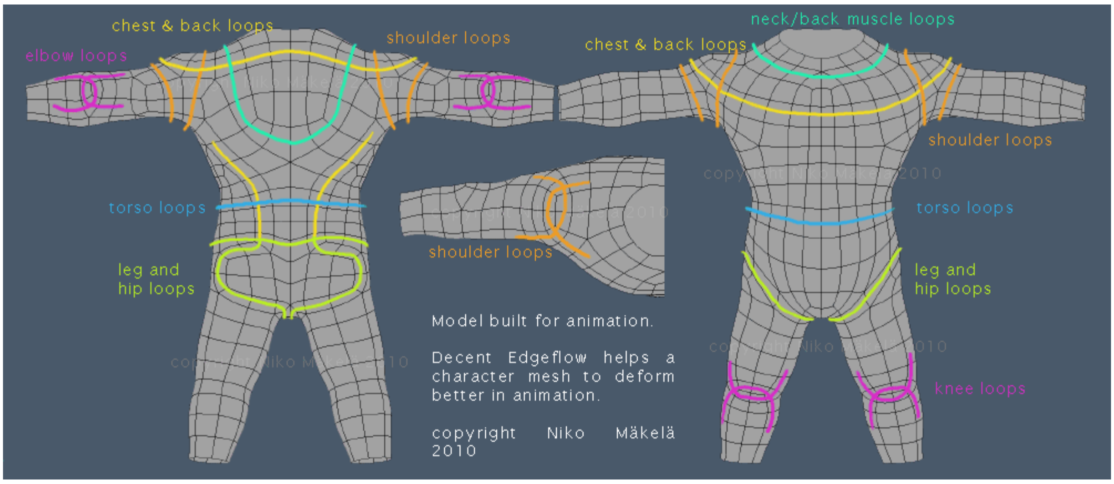

Figure 2.9: Body edgeflow. (Niko Mäkelä 2010)

When creating the body, it's important to take in to consideration the main moving masses of human/humanoid. You want to create edge loops that follows the bigger muscles under the skin, it can get needlessly complex considering how many muscles there are in the human body, but you only really need loop for the main muscle groups or body masses to get good deformations and to get the right idea of the look. [15]

[15] Niko Mäkelä, (2010), "*Modeling for animation - Body*", CGmascot

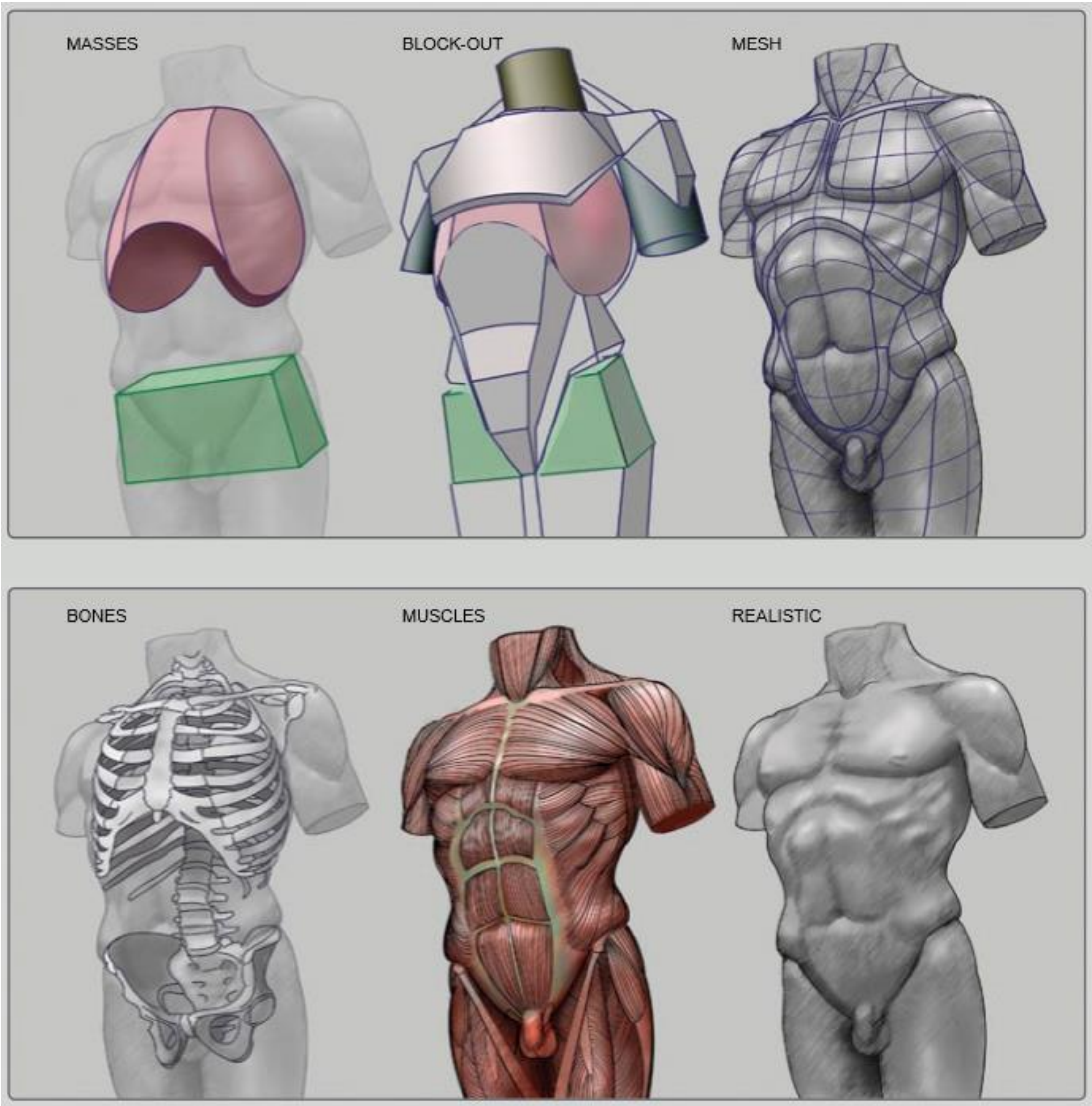

Figure 2.10: Male torso from realistic to simplified (Uldis Zarins 2014)

To create a good shape of the chest and back you will need edge rings going around the torso. As stated in the shoulder part one problem area is where the arm connects to the torso. You want to have edge loops going from the chest over the shoulders. [16]

Figure 2.10 show the basic forms of the human male body and some simple flow of it. When creating our topology, we need to have these forms in mind to get the right edgeflow.

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[16] Niko Mäkelä, (2010), "*Modeling for animation - Body*", CGmascot

3 Method

3.1 Test

To test the theories described in the chapter above I decided to re-top a character topology in two different ways. One is to take all the things written above into consideration when creating the model and the other not taking this into consideration. Some parts became quite similar such as the chest, shoulders and pelvis.

They were both modeled in A-pose to have more natural shoulders with less stretch and to help the solvers know how the limbs would bend. The characters are done on a quite low polygon budget since I didn't want to waste time creating complex models just for simple tests, that's also why the head and hands are as simple as they are.

The models have a quite low polygon count since it's easier to see how a single polygon deforms when each polygon is bigger. This might create some problems as well. The two characters have around 1900 tris each.

The two models then where rigged and weight painted before running the same skinning test animation from mixamo.

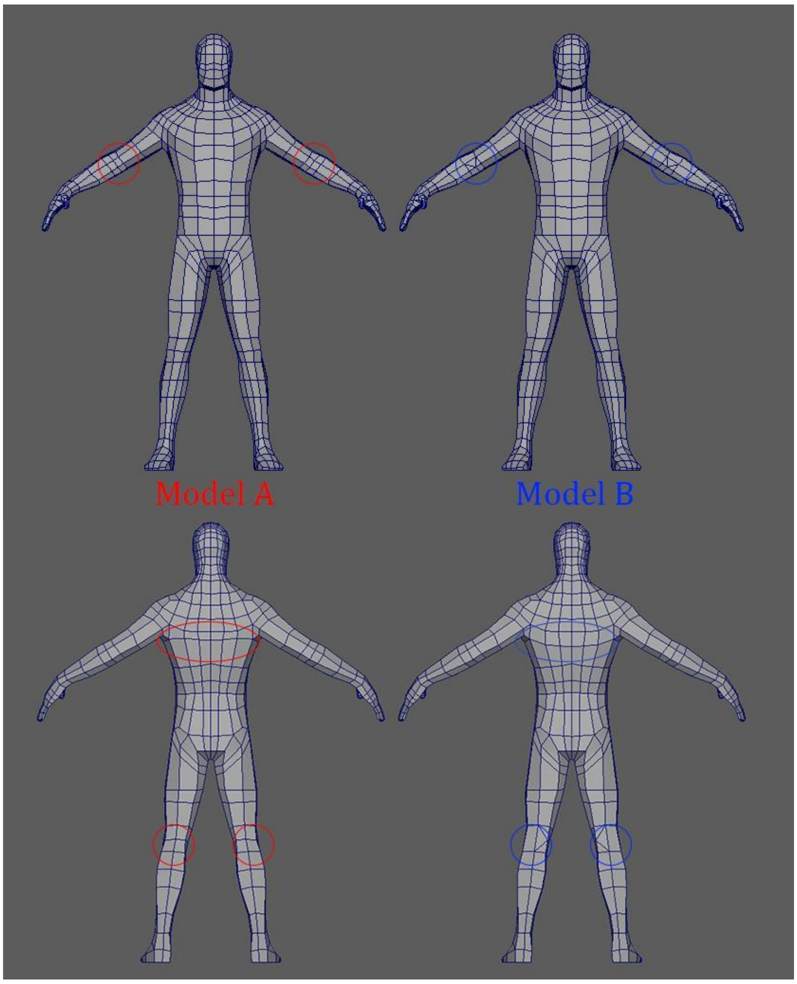

Figure 3.1: showing my two test meshes with circles showing the differences (Me 2018)

3.1.1 Shoulders

Both models follow the same theory with having edge loops going around the chest and up on the shoulders with a x loop to define the shoulder.

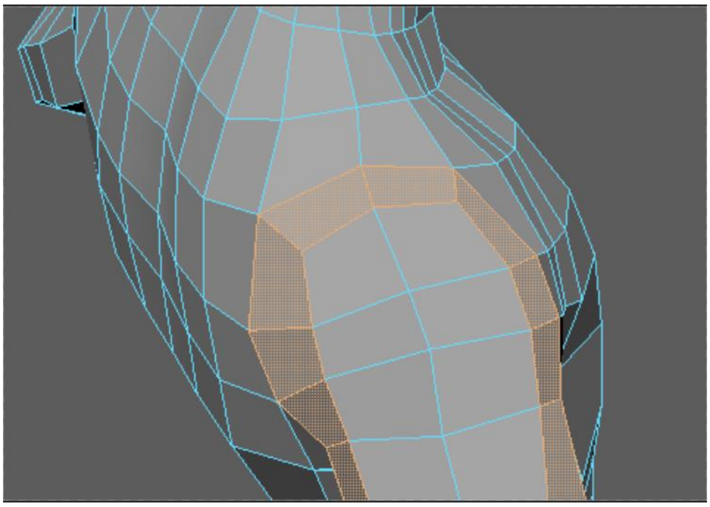

Figure 3.2: the shoulder x-loop (Me 2018)

3.1.2 Knees and elbows

The two models use the two different methods mentioned in the literature chapter. Model B use the triangles on the backside of the knees and the backside of the elbow. While model A use normal edge loops.

3.1.3 Body

Both bodies mainly follow the guidelines made by Mäkela with how the edge loops flow on the model. Model B's edge loops follow the shape of the rib cage better than model A's does. This makes the bending of the torso look more realistic and follow the shape of the human body.

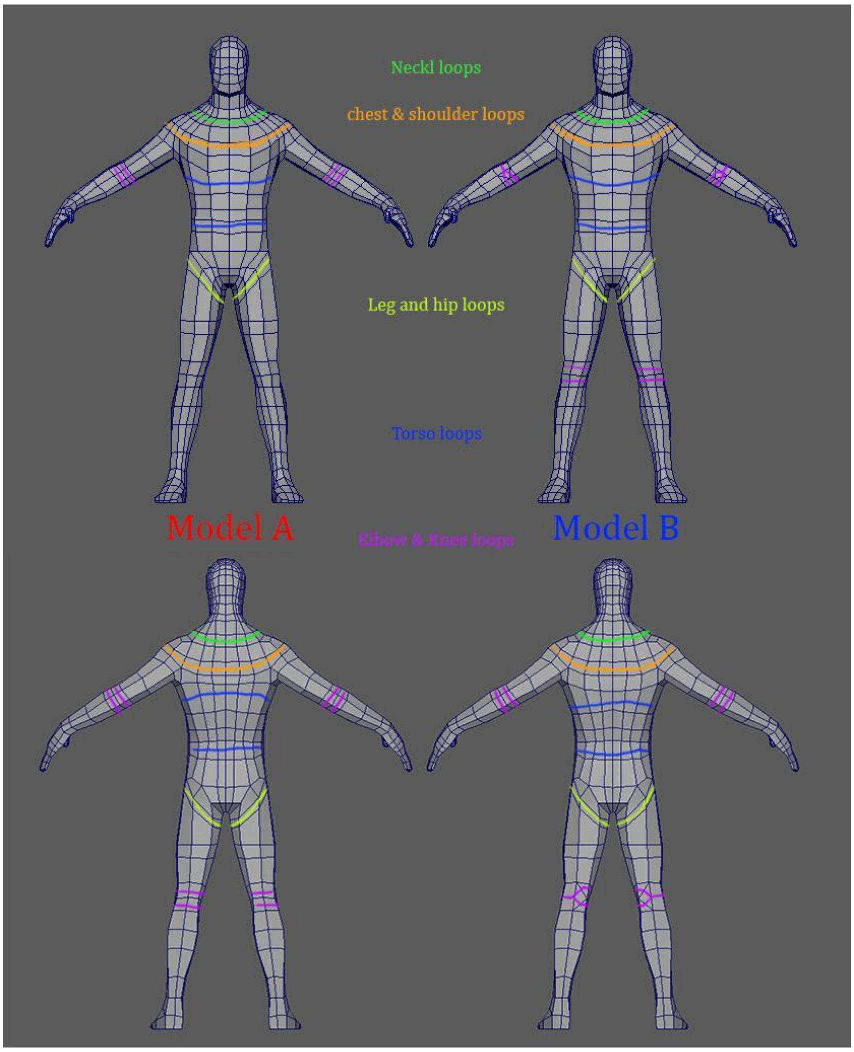

Figure 3.3: Edgeflow of my models (Me 2018)

3.2 Skinning test sequence

The following figures are still frames of the two models (A in red and B in blue doing the same skinning sequence from mixamo. The skinning test sequence are 55 frames long and made to see how the skinning looks on the character.

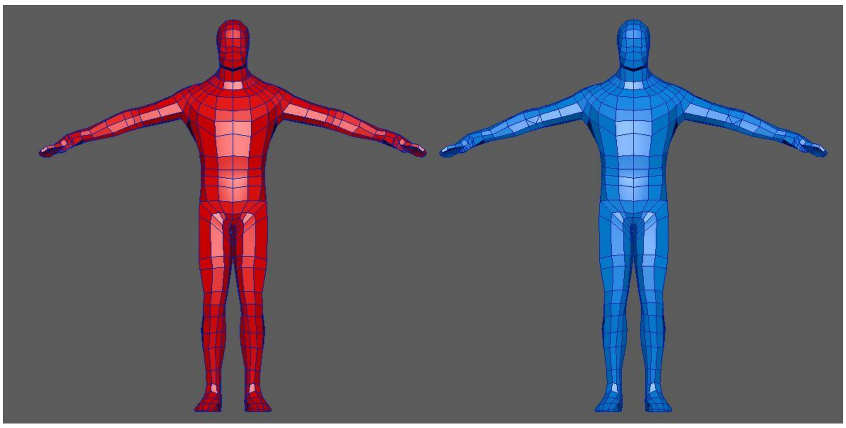
Figure 3.4: Frame 01 from skinning sequence (Me 2018)

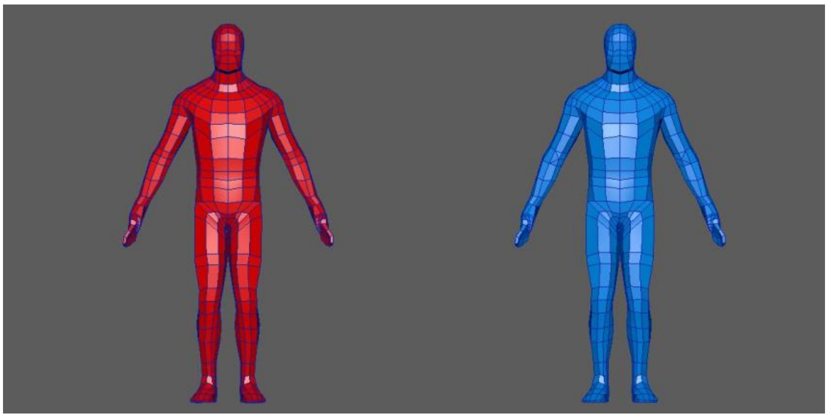
Figure 3.5: Frame 04 from skinning sequence (Me 2018)

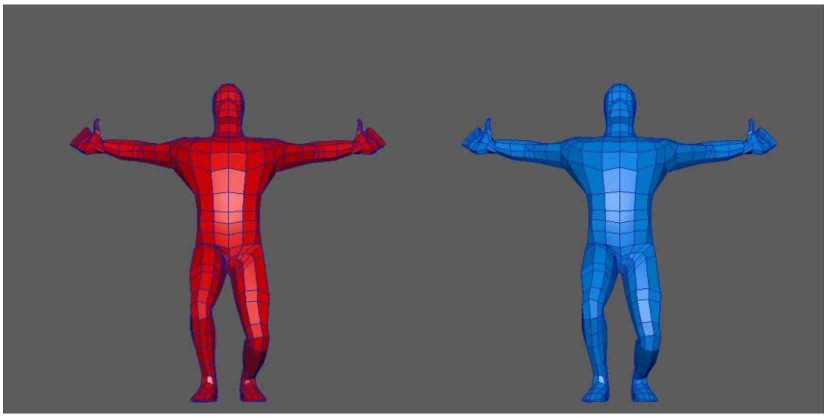
Figure 3.6: Frame 08 from skinning sequence (Me 2018)

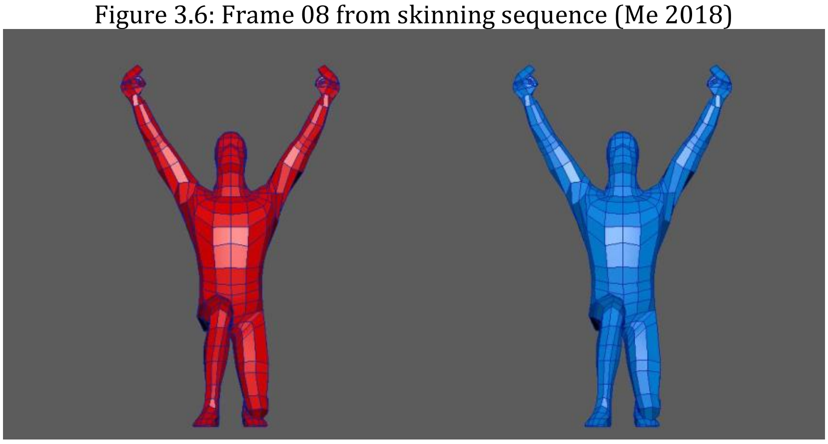
Figure 3.7: Frame 12 from skinning sequence (Me 2018)

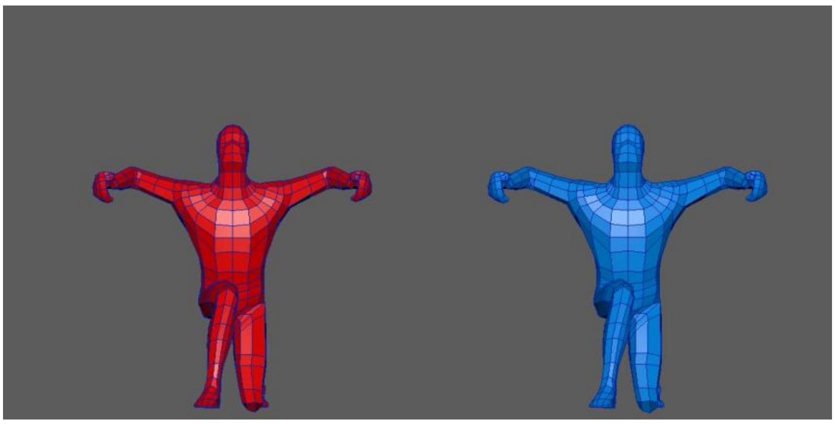
Figure 3.8: Frame 15 from skinning sequence (Me 2018)

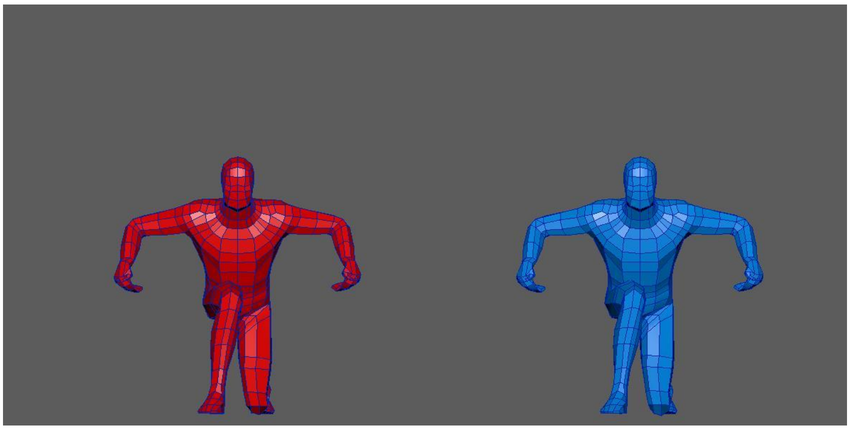
Figure 3.9: Frame 18 from skinning sequence (Me 2018)

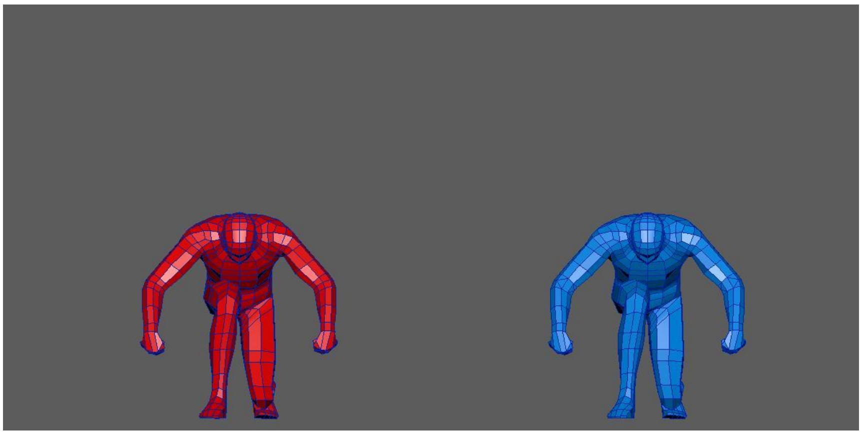
Figure 3.10: Frame 21 from skinning sequence (Me 2018)

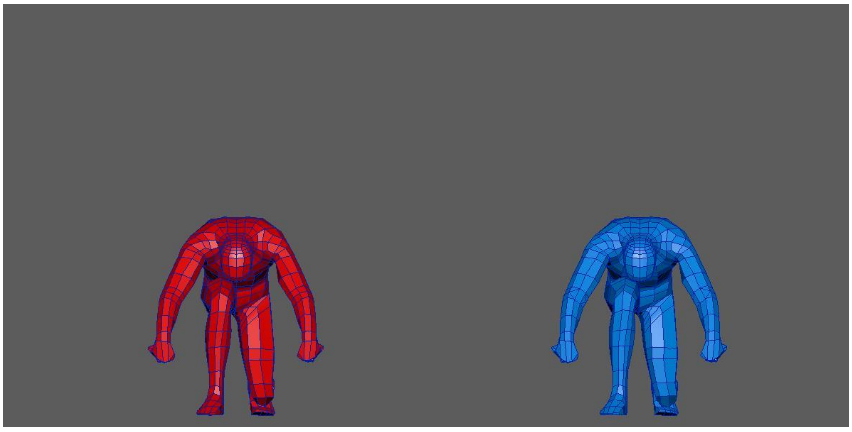
Figure 3.11: Frame 23 from skinning sequence(Me 2018)

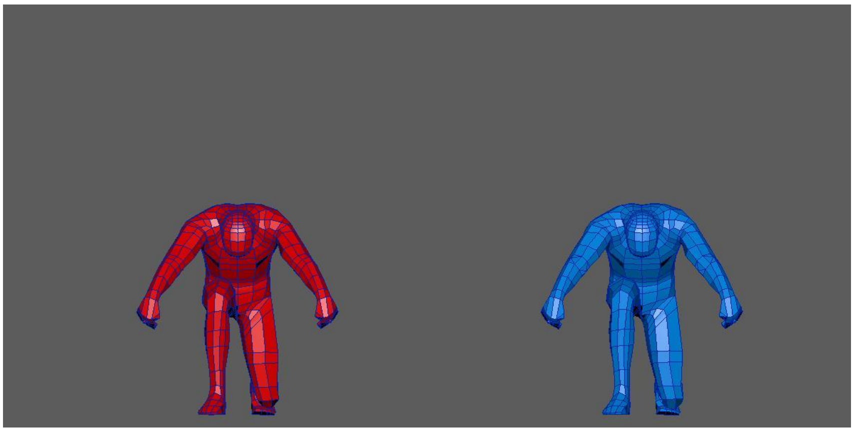
Figure 3.12: Frame 26 from skinning sequence (Me 2018)

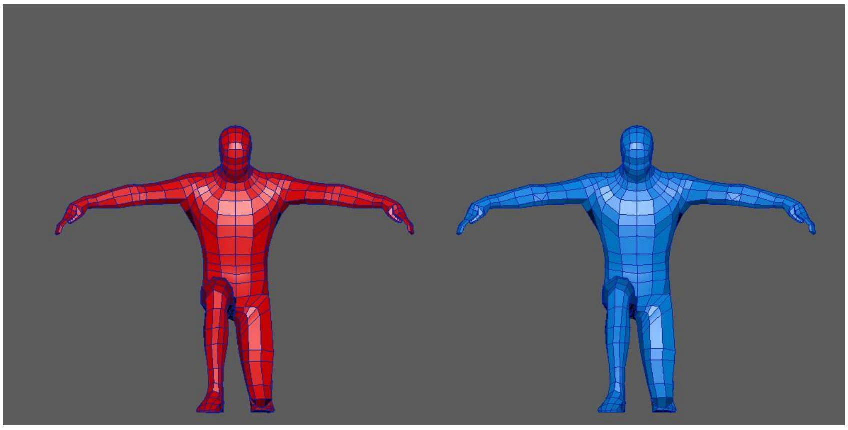
Figure 3.13: Frame 30 from skinning sequence (Me 2018)

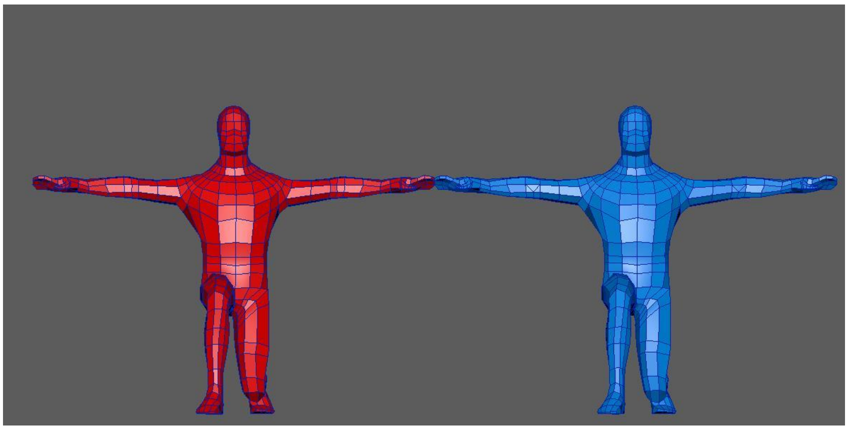
Figure 3.14: Frame 33 from skinning sequence (Me 2018)

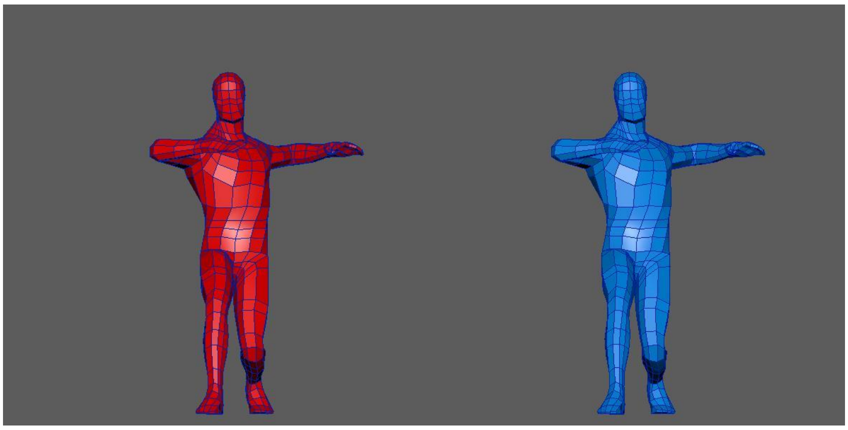

Figure 3.15: Frame 38 from skinning sequence (Me 2018)

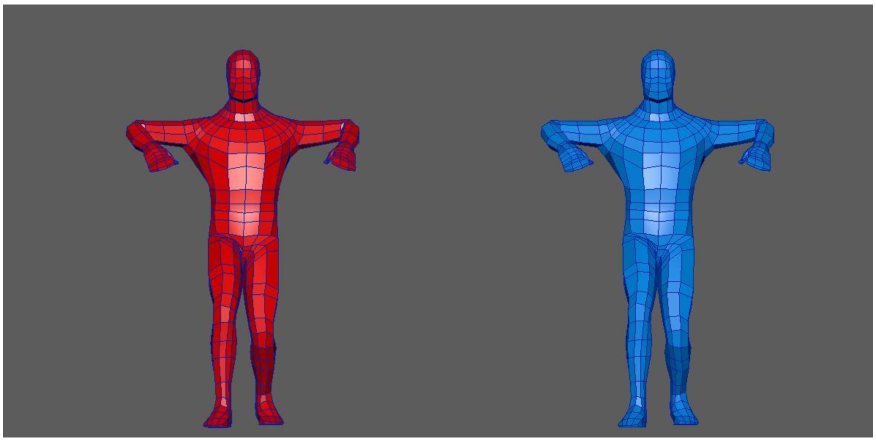

Figure 3.16: Frame 41 from skinning sequence (Me 2018)

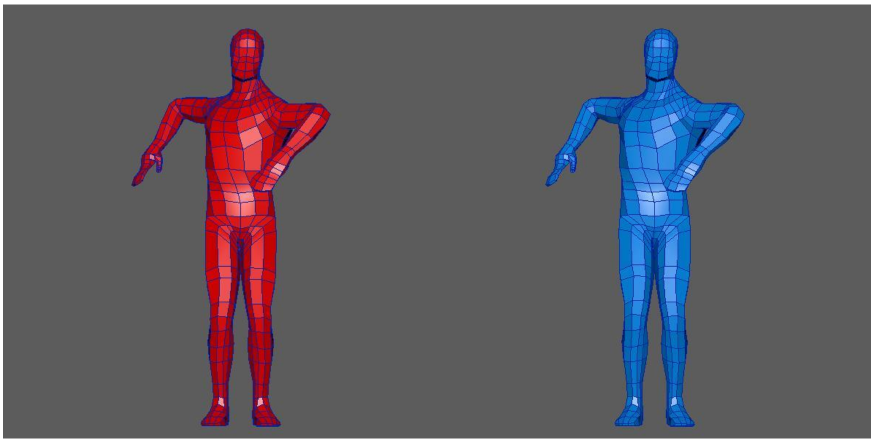

Figure 3.17: Frame 47 from skinning sequence (Me 2018)

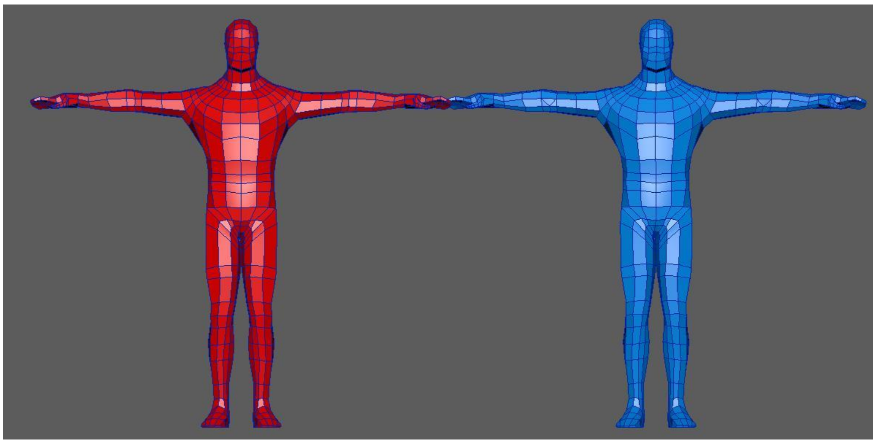

Figure 3.18: Frame 55 from skinning sequence (Me 2018)

3.3 Method critique

Some of the things mentioned would have worked differently if more time were put into weight painting since it was not the focus of the thesis I didn’t go too far in to it, it might have had a hole other outcome if someone else would have rigged it and done the weight paint.

There are also some trouble areas know that would have been fixed better with a higher polygon budget. Since adding more polygons create less stretching on each polygon.

This test also only includes one body type as it might be some differences when creating topology for females or heavier/skinnier humans.

4 Results

4.1 Shoulders

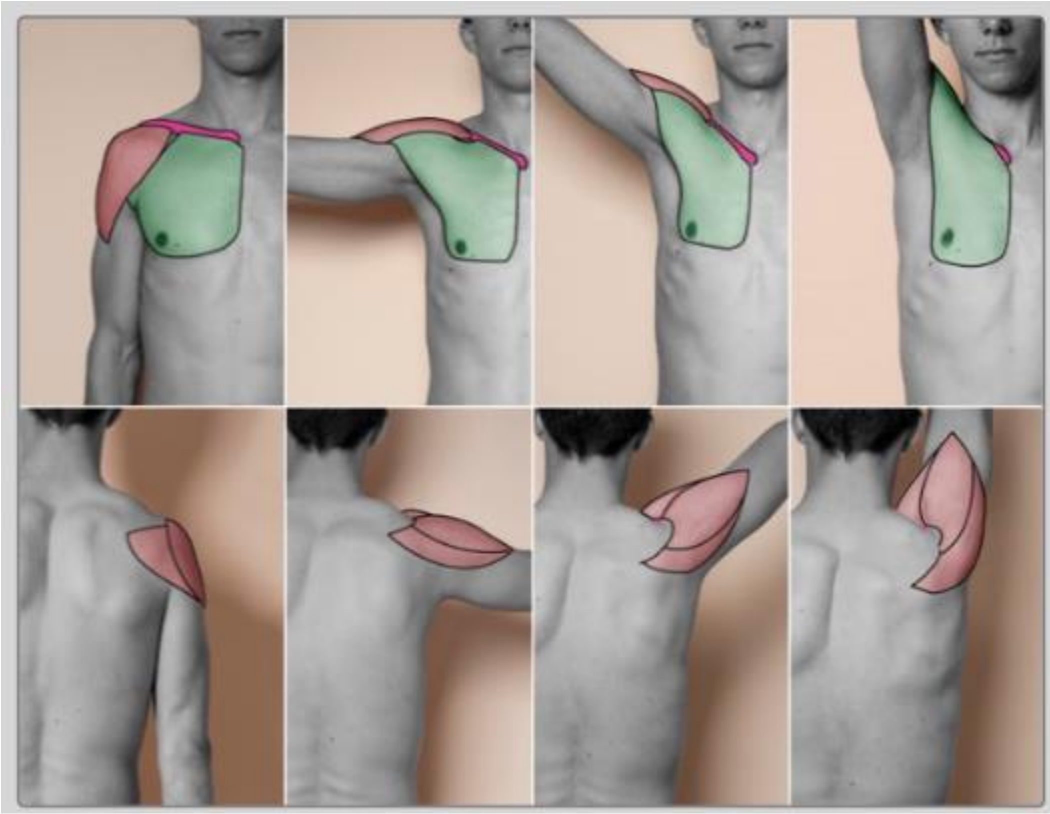

Figure 4.1: shoulder movement (Uldis Zarins 2014)

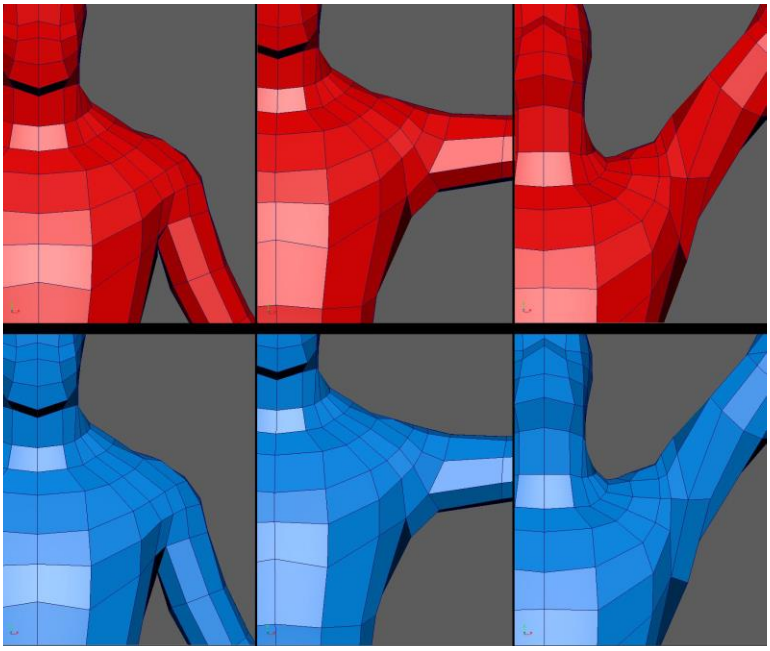

Figure 4.2: Shoulder comparison front (Me 2018)

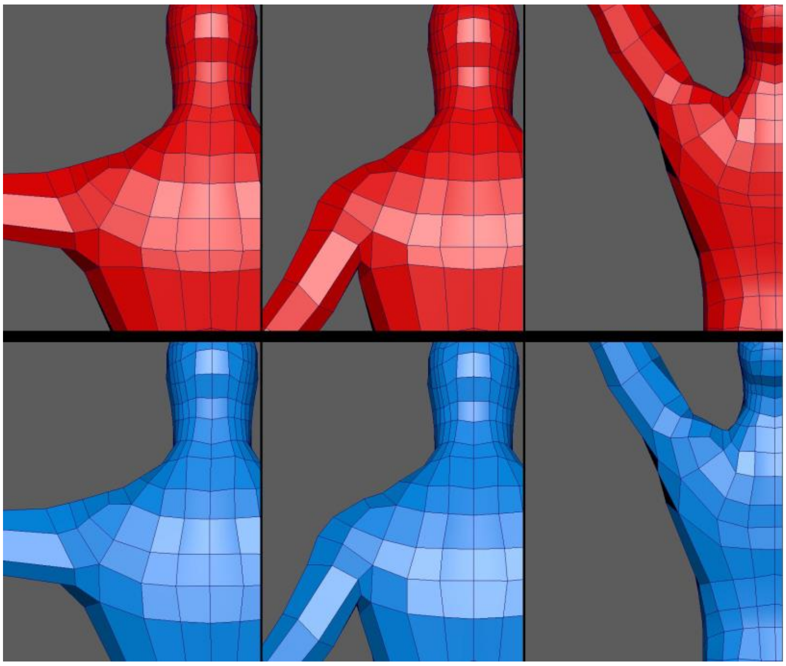

Figure 4.3: Shoulder comparison back (Me 2018)

The shoulder of both my characters have the same edgeflow. The edgeflow of the shoulder isn’t the best and has some problems. The geometry under the arm seams to follow the arm more than it does in the reference images in figure 4.1

4.2 Knees and elbow

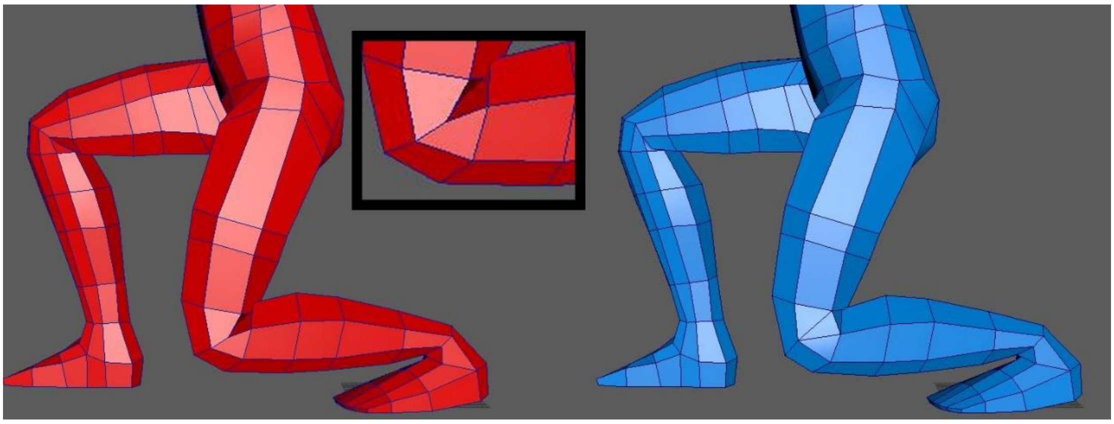

Figure 4.4: my models bending down (Me 2018)

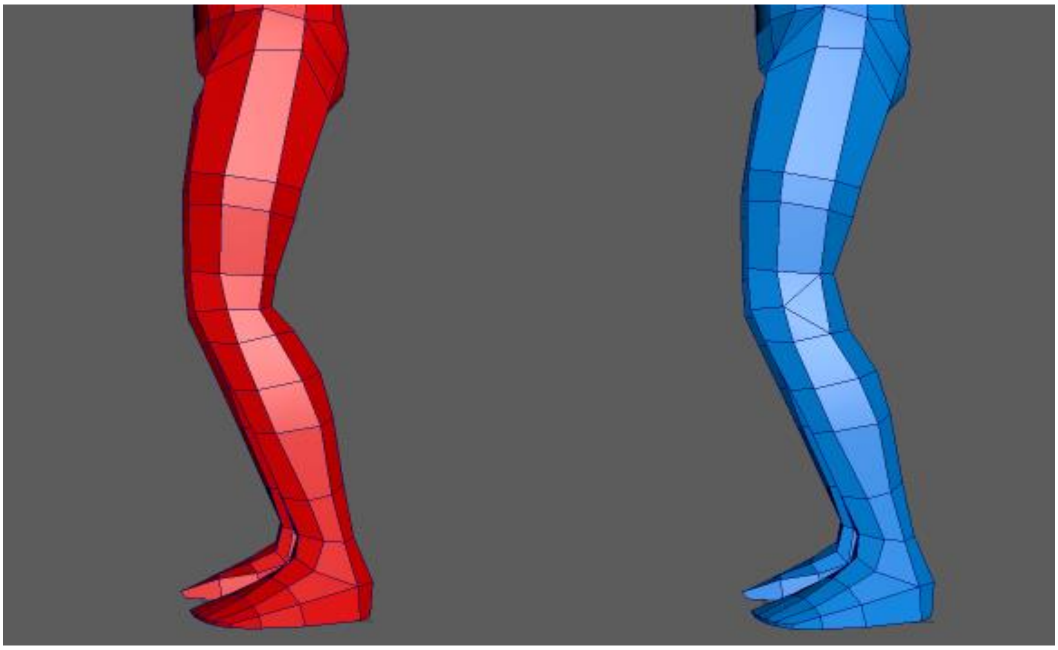

Figure 4.5: my models standing up (Me 2018)

Figure 4.6: Knee bending (Uldis Zarins 2014)

The knees on model A (red) in figure 4.4 the hollow of the knee collapses creating geometry going inside itself. The leg on model B (blue) looks much more like the real leg in figure 4.6.

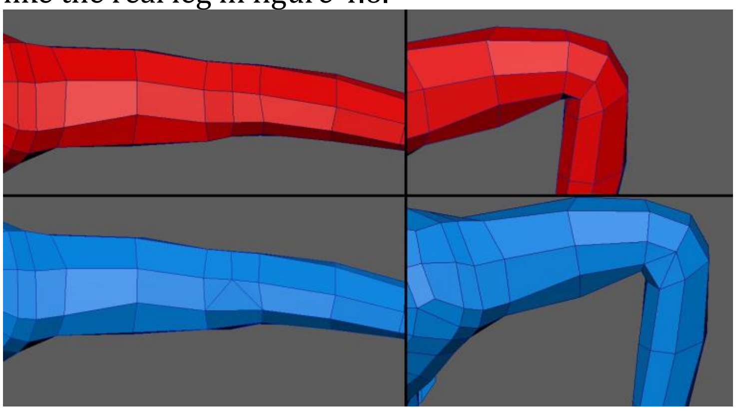

Figure 4.7: Elbows bending (Me 2018)

The same is true about the elbows as well.

4.3 Body

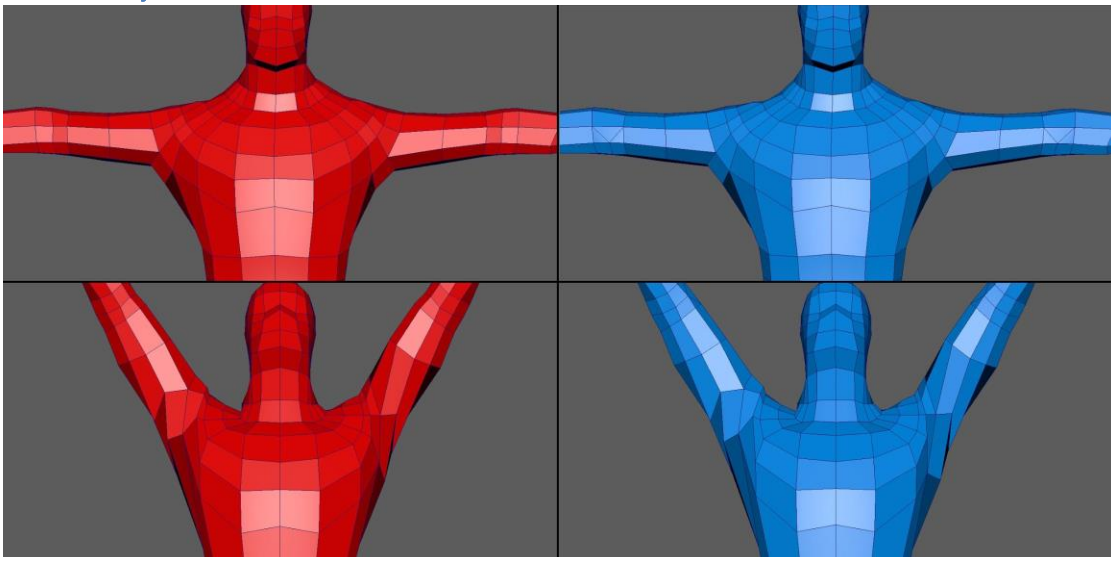

Figure 4.8: Chest of the two characters (Me 2018)

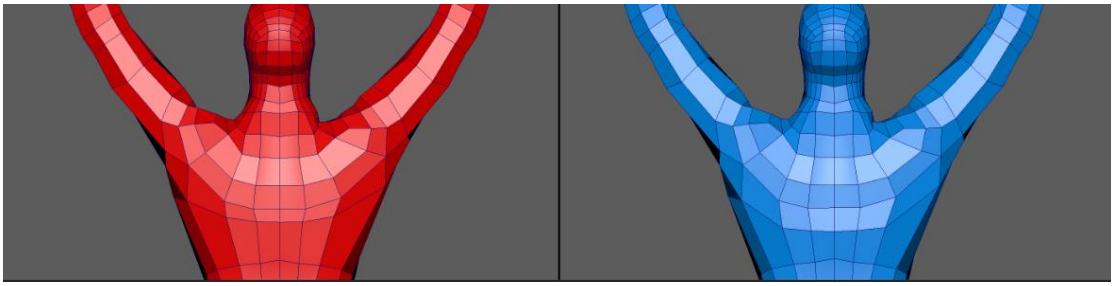

Figure 4.9: Backs of the two characters (Me 2018)

Figure 4.10: Male arms out and up (Uldis Zarins 2014)

Here we can see that the muscles under the arms extends when the arms are lifted up. On my characters the armpit is a problem since it has a duller angle then the model in figure 4.x who has a very hard angle under his arms.

There are also some troubles with the twist on the over arm since the rig mixamo uses don't have any twist joints.

5 Discussion

The original question was "what should you think about when creating a game character?". During the research of this thesis I have conclude that it's quite a lot and it's quite hard to get information about it other than from forum post or pictures people post as examples. When comparing my result with real photos some problem areas occur.

5.1 Shoulders

The skinning sequence didn't have an extreme pose with arms straight up so it's hard to see to a hundred percent how the shoulder would react to that.

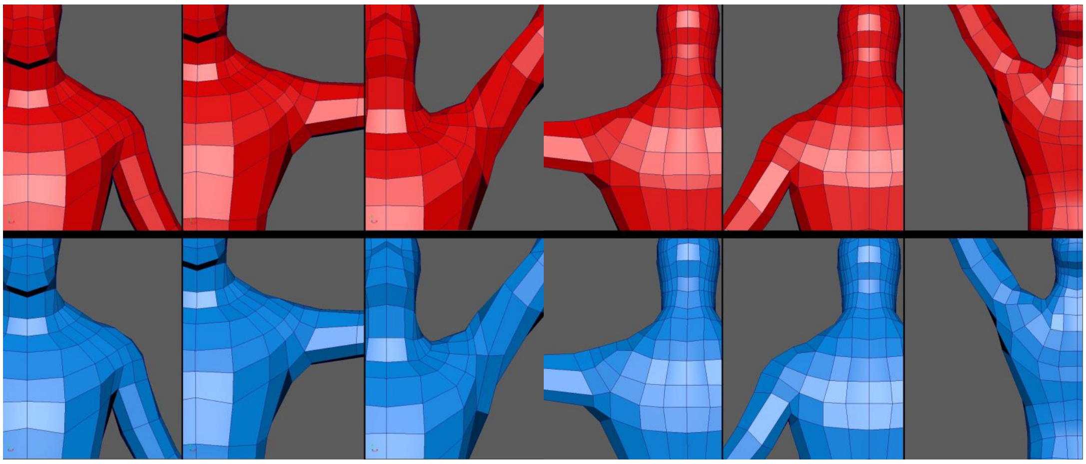

Figure 5.1 & 5.2: Shoulder movement from front and back (Me 2018)

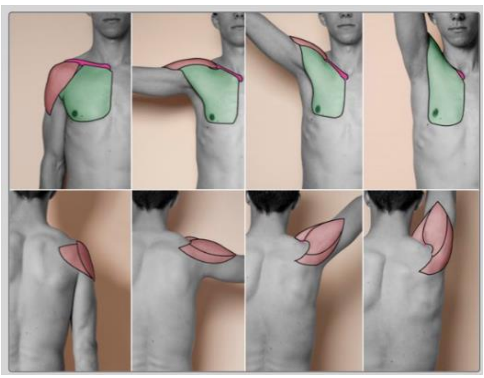

Figure 5.3: Shoulder movements (Uldis Zarins 2014)

When the arms are straight down the shoulder compare quite well with the real-life model's shoulder. The shoulder with this topology overall follows the movement and shape of the real shoulder quite well.

5.2 Knee and elbow

The knee is a real trouble area. When comparing the two models with each other and reference pictures it's easy to see why the method with just edge loops used on the red model isn't something you want.

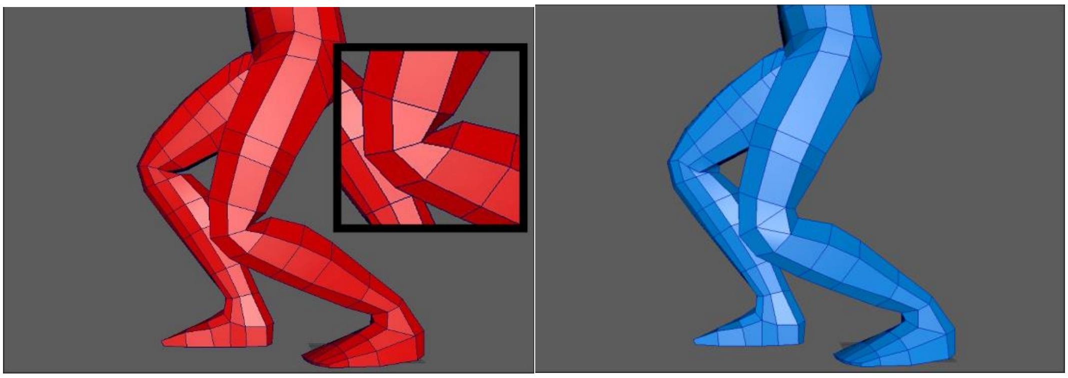

Figure 5.4 & 5.5: Model A bending knees (Me 2018)

The hollow of the knee collapses when bent creating a sharp edge. This looks unnatural compared to a real human. When comparing figure 5.4 and figure 5.6 it's easy to tell that the legs in 5.4 doesn't look natural.

Figure 5.6: Knee bending (Uldis Zarins 2014)

When comparing the legs in figure 5.5 with figure 5.6 we can see that they keep their form much better and we can see that we don't get the hard edge where the edge loop collapse. The problem with this design is the 45-degree angle that occurs with the edge loops in the hollow of the knee. This might be a problem with how I set up the edge loops since in figure 5.4 by polycount this isn't as big of a problem.

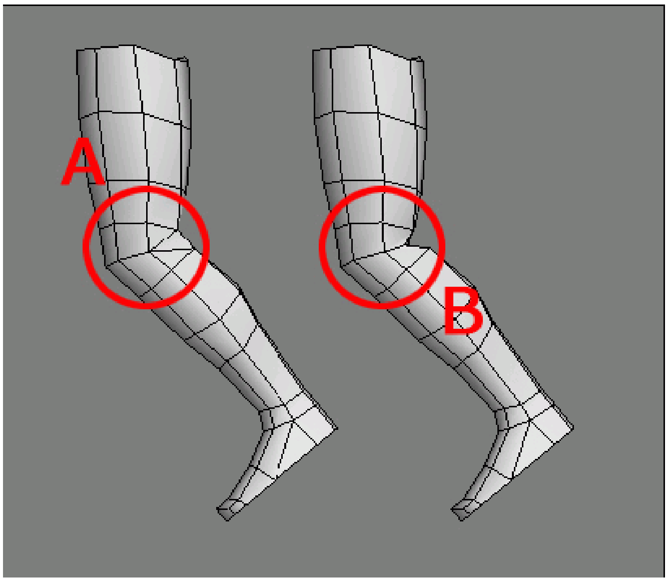

Figure 5.7: Leg topology. (Polycount, 2015)

This might be a problem with either how I set up the edge loops or with the weight paint.

The elbow work in much the same ways as the knee and has some similar problems.

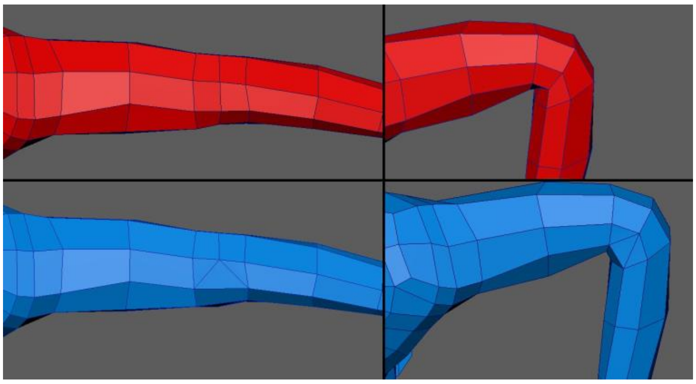
Figure 5.8: Elbow bending (Me 2018)

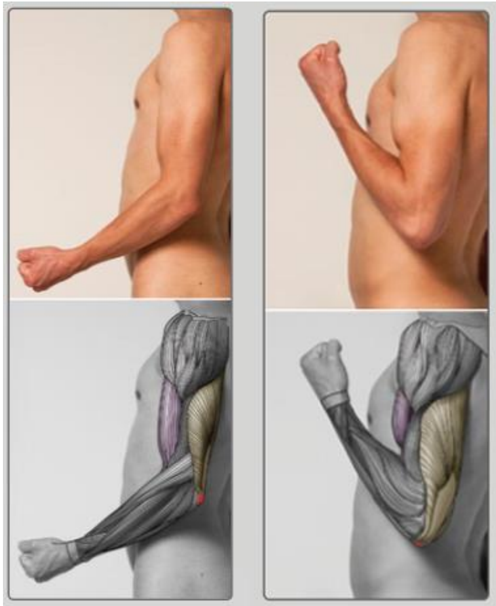

Figure 5.9: Arm bending (Uldis Zarins 2014)

The problem with the elbow is that when it's bent it loses some of it shape. A real elbow as shown in figure 5.7 has a quite sharp outer angle when bent. This might also be a problem with the weight paint on my models. The inner angle of the elbow on model A much collapses much like the knee creating sharp edges and unrealistic shapes compared to the references in figure 5.7. The inner angle of the elbow on model B looks much closer to the real-life references.

5.3 Body

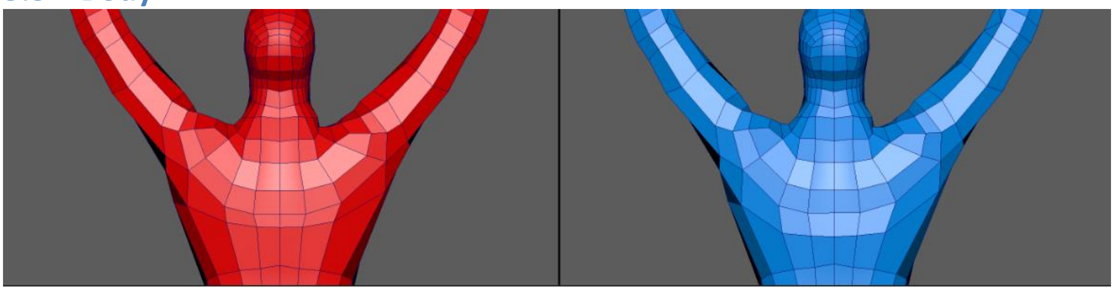

Figure 5.10: Backs of the two characters (Me 2018)

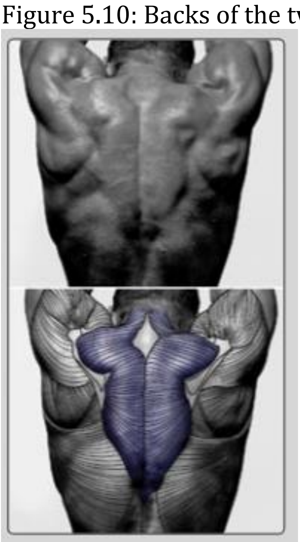

Figure 5.11: Back muscles (Uldis Zarins 2014)

Comparing my characters backs in figure 5.10 with the back of a real model in figure 5.11 we see that the last edge loop going from the shoulders better follow the muscles on model B create in better shapes. The lowest edge loop on both models in figure 5.10 could be improved to better follow the lines of the rib cage and the back muscles.

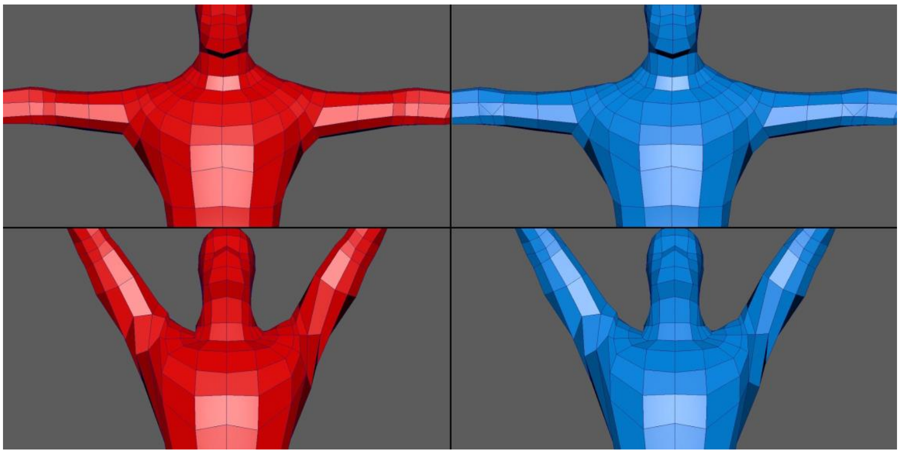

Figure 5.12: My models chest (Me 2018)

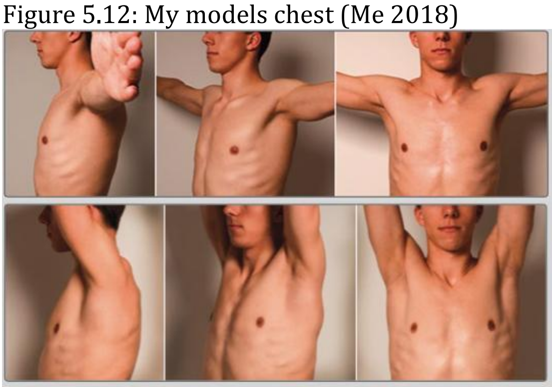

Figure 5.13: Male arms to the side and arms above head (Uldis Zarins 2014)

Comparing my model's chests in figure 5.12 to the real chest in figure 5.13 we can see that the edge loops follow the lines of the chest and the rib cage quite well. The deformations are not the greatest the side of the rib cage gets a little too triangular when the arms are raised. This can though be seen in the pictures where the arms are just to the sides as well. My models have bigger muscles under the arms then the model in figure 5.12. So, this might just be a problem with the person in the picture and my models having different body types. The person in figure 5.11 gets a closer result to my models.

6 Conclusion

There are a lot to be learn of how you set up the topology of your character and a lot to keep in mind. the methods I bring up in this thesis are a good beginning but it's only the tip of the iceberg. You learn the most by trial and error as stated before in the thesis.

One thing to take in to consideration as well are the number of polygons you're using, in my experiments I was quite sparse with my polygon budget. So, some of the methods in this thesis might not work on characters with higher polygon budget but most of the mindset should be the same.

It's good to learn the basis of anatomy and consider the way the character is supposed to move. The subject of topology is a subject that are hard to find exact information about as most people have their own way of doing it that works for them. So, you need to find what works best for you, but a good basis is to follow the shape and the flow of the human body.

There are more areas that I didn't bring up in this thesis in details, such as the pelvis and face. These areas are quite complex and needs a lot of consideration when creating their topology.

To continue the work, one might want to create more variations on the characters to learn more of what works and what doesn't work also take into consideration the head, hands and pelvis.

7 Bibliography

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8 Appendices

Images

Figure 2.1: By Brian Tindall - http://www.hippydrome.com/ArmsShldrRot.html
Figure 2.2: By Jonathan Williamson - http://wiki.polycount.com/wiki/ShoulderTopology
Figure 2.3: By Niko Mäkelä - http://www.cgmascot.com/design/modeling-for-animation-body/
Figure 2.4: By A.Wiro - https://www.3dm3.com/tutorials/female_body/
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Figure 3.9: By Me - screenshot from maya of animation sequence
Figure 3.10: By Me - screenshot from maya of animation sequence
Figure 3.11: By Me - screenshot from maya of animation sequence
Figure 3.12: By Me - screenshot from maya of animation sequence
Figure 3.13: By Me - screenshot from maya of animation sequence
Figure 3.14: By Me - screenshot from maya of animation sequence
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Figure 5.13: By Uldis Zaris - "*Anatomy for sculptors*" P. 75 & 79 edited by me