3D-animation in VR-software

Case: CB-Safe project

LAB-ammattikorkeakoulu
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Tutkimuksen tavoitteena oli 3d-hahmojen luonti ja animointi Virtuaalitodellisuus -ympäristöön CB-Safe pelastussimulaatiota varten yleisohjeeksi projektin jatkokehitystä varten. Työssä esitettiin, mitä Virtuaalitodellisuus tarkoittaa sekä sen hyvät ja huonot puolet, että käyttömahdollisuudet, jonka perusteella luotiin yleisohjeet 3d-mallinnusta ja animaatiota varten. Yleisohjeisiin kuului 3d-mallien eli Meshien määritelmät, koostumukset, muokkaustavat, väritys ja koristelu eli teksturointi ja 3d-luuranko. Animaatioon kuului Avainkehysten, Aikajanan, F-Curvien, Inter- ja Extrapolaation käyttö sekä Blender-ohjelman animaatiotyökalujen esittäminen. Case-osuuteen kuului ohjeet CB-Safe pelastushahmon ja sen animaatioiden valmistamiseen, testaustulos Unity pelimoottorissa ja miten 3d-hahmo optimoidaan VR-käyttöön. Tuloksiksi saatiin polygonien rajoitettu määrä 3d-hahmoissa, joka vähentää tehonviehtiä VR:ssä, sekä F-Curvien käytön suosittelu animaation ajanhukan vähentämiseksi.

Asiasanat

Avainkehys, Blender, F-Curvi, Mesh, Polygon, Virtuaalitodellisuus

Abstract

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Abstract

The goal of the thesis was to instruct the creation of animated 3d-characters to a Virtual Reality -environment for the future development of CB-Safe project. It was explained what Virtual Reality means, what its good and bad sides and usage possibilities are, through which a guide to produce animated 3d-characters was created. The guide included the definition, composition, editing methods, coloring, and decorating i.e texturing and rigging of 3d-objects called Meshes. The animation included the use of Key frames, Timeline, F-Curves, Inter- and Extrapolation, and the presentation of Blender's animation tools. The case section included instructions for making the CB-Safe rescue character and its animations, the test result in the Unity game engine, and how to optimize the 3d character for VR use. The results were to limit the number of polygons in 3d characters, which reduces power consumption in its use in VR, as well as a recommendation to use F-Curves to reduce the waste of time when animating.

Keywords

Blender, F-Curve, Keyframe, Mesh, Polygon, Virtual Reality

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1 Introduction

The objective of the thesis is the use of 3D-animation using a Blender 3D-modeling software, and its sub-areas in Virtual Reality. The sub-areas include 3D-character animations, motion capture animations, 3D-characters, and Blender animation techniques. The thesis examines the general areas of 3D-character animation and how to implement 3D-animation practices for VR-environments. The thesis introduces what Virtual Reality means, 3d-animation in VR and the good and bad parts of VR, 3d-modeling and what is needed to have a 3d-character ready for animation and how to optimize it for VR-simulations, how 3d-character animation is made and its sub-areas, and animation techniques for Blender. The thesis focuses on using Blender 3d-modeling software for its examples, and is the program used for creating and animating 3d-models in the Case. The research methods used are analysing professional literary sources and work experience. The thesis is a case study of 3d-character movement animations in CB-Safe rescue simulation for VR and it introduces the background of the project and the steps to create a functional 3d-character. The thesis does not take a stand for animating clothes or hair but does include modelling clothes on characters for using them as part of the movement animations.

2 3D-characters

2.1 Virtual Reality

Virtual Reality is a computer-generated environment that appears as if it was real, allowing the user to be immersed with their surroundings as seen in figure 1. Virtual reality -animation means animations in a virtual reality -environment. However, not all animations inside a VR-environment can be considered as such. Animations that are the result of a real person moving with VR-equipment, or animations that can interact with, or can be interacted by a real person are considered Virtual Reality animations. Completely predetermined animations that are unresponsive to a VR-avatar, e.g. a non-playable character walk cycle are normal 3d-animations despite being in a VR-environment. A VR-avatar is a 3d-character in the VR-environment that the user controls. (Ismo Jakonen 2020.)

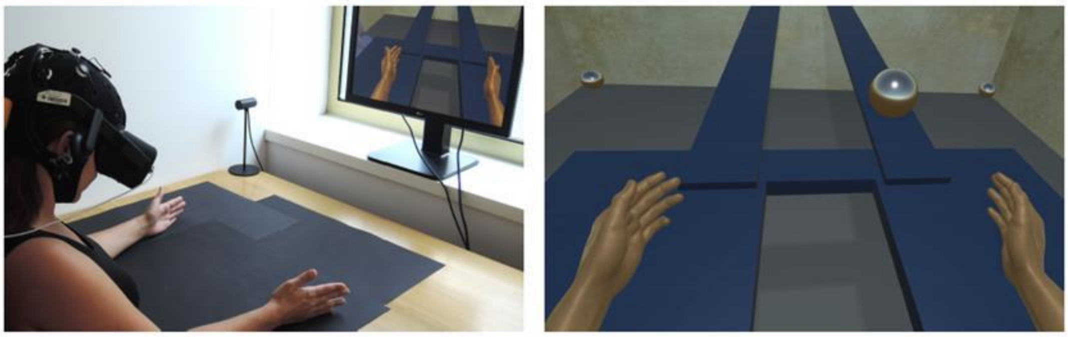

Figure 1. Virtual Reality environment (RISE 2020)

Virtual reality acts as a medium which allows one’s full senses such as sight, hearing and touch to participate and be fully immersed in the generated reality or environment. This means a person’s virtual avatar in the virtual world is fully animated in real time by their actions in real life using physical mediums such as jigs, gloves, and a visor. Eye and body movements are tracked and will react to actions a real person is doing. Extending a hand holding a jig will also make the virtual avatar extend their hand the same way and turning a head while wearing a visor will make the virtual avatar turn its head. (Hong Kong Virtual Reality a.)

VR animation can increase emotion, attachment, and interest by being fully incorporated into whatever is happening, rather than being more detached like with traditional 3d-animation. Virtual reality is also a bridge to fully take advantage of the the 3d-world and utilize a better viewing and overall experience. (Hong Kong Virtual Reality a.)

Virtual reality has gained many different uses and has great popularity in sectors such as entertainment, gaming, mobile applications, and different simulations. Virtual reality allows simulation for training, education, health care, museums, space exploration, engineering, and manufacturing. Many offerings for VR are emerging from the military, retail, and legal procedures, with many more applications being developed every day. (Hong Kong Virtual Reality a.)

Positive sides of VR are face-to-face communication and interaction during training or simulations for engaging, active attendance and real-time interactions, enhanced learning processes from turning theory into action, accessibility from being able to meet over long distances without having to travel anywhere, and customization for desirable virtual meeting or training platforms. (Hong Kong Virtual Reality b.)

Negative sides of VR are the very expensive equipment that is required for VR, creating meeting platforms or simulations can take a lot of time and money, technology restrictions, motion sickness and dizziness from moving in the virtual environment, accidents such as falling over or hitting objects in real life from not being able to see from under the visor and eye straining. (Hong Kong Virtual Reality b.)

There are some restrictions in the modern VR-technologies. For example, creating interactable VR-simulations is more complex and difficult than something experienced with a keyboard and mouse, simulations need more processing power to run and being a relatively new technology that is still developing. Not only are certain VR-equipment e.g. contact gloves that give a sensation of touch extremely expensive but even the cheaper equipment also cost a lot. There are also technological restrictions such as the various equipment models not necessarily being compatible with computers and requiring effort to set up. Virtual Reality also requires a platform to use it in, such as Unity game engine with VR-capabilities. (Ismo Jakonen 2020.)

2.2 Development

3D-characters are 3-dimensional character models made from a collection of polygons, vertices and textures that are capable of being animated in a 3d-modeling program e.g. Blender, 3DS Max or Maya. The process of creating a 3d-character is usually preceded by a pre-processing phase. The pre-processing phase usually consists of designing and planning what the model should be like, the concept phase. The concept phase consists of creating a concept of the character, sketching early pictures of the model, sketching detailed pictures of the chosen idea or using reference pictures if the target of modelling exists in reality, building and improving on the chosen ideas, creating character sheets with pictures of the to-be-made character model from all sides and colour variations with what materials are to be used, the level of detail and therefore amount of polygons needed, a timetable and finally deciding on what 3d-modeling program to use. (Lookinar 2020.)

After the pre-processing phase comes the Blocking phase. The Blocking phase is the creation of the basic mesh with the correct proportions for the 3d-character and testing what later additions e.g. clothes look like on the model using low-polygon substitute or placeholder models. (Lookinar 2020.)

After the Blocking phase is the Sculpting phase. The Sculpting phase consists of modifying the basic mesh with details into a shape as shown in the character sheet. The 3d-character should be as detailed as possible in proportion to the desired amount of polygons and level of detail. The basic mesh should be detailed first and then clothes and other separate parts. To keep an optimal polygon count, places on the mesh that will never show from under the clothes should stay undetailed. In this phase, the 3d-modeler should use all their knowledge and skills to create a perfect, finished product as there will be little possibility to modify the shape of the character afterwards. The polygons should be in a flow, especially in the face. Flow means a flowing loop of square polygons, see figure 2. (Lookinar 2020.)

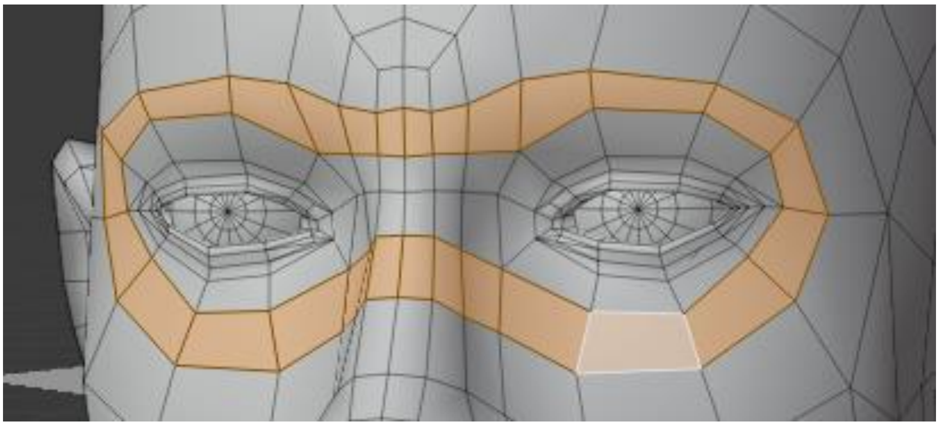

Figure 2. Flow (Picture: Henrik Wiiala)

After the detailed model is ready, the 3d-character must be processed to decrease excess polygons to decrease the amount of processing power for any program that uses the model expends. This phase is called retopology. (Lookinar 2020.)

Once the 3d-character model is ready, it must be textured, rigged, skinned and weight painted. The first stage of texturing is unwrapping the model into clear areas e.g. chest, abdomen, upper back, lower back, arms, legs, head, face, palms and even fingers for both the model and clothes where various textures are applied to. Unwrapping converts the marked 3-dimensional areas into a 2-dimensional canvas where textures can be applied easily. The textures must be opened in the UV editor and the vertexes of unwrapped areas dragged to the desired textures. The textures are then applied to the materials found in the 3d-editor which are applied to the 3d-character. Rigging is adding a skeleton of bones called Armature to the 3d-character. Bones are hierarchical, with bones being either parents' bones with child bones or being child bones of parent bones. Bones control areas of the vertexes around them, allowing the vertexes to move when the bone is moved. Skinning is linking the armature to the 3d-character mesh and modifying the Vertex Groups, so the bones only control the desired vertexes and not any it is not supposed to. Weight painting is adding weights to the 3d-character mesh, meaning the more weight an area of vertexes has, the less moving the bones affect the Vertex Groups surrounding the bone. If a joint has a lot of weight, it will stop at a certain area and not clip inside the character when moved. (Lookinar 2020.)

2.2.1 3D-modeling

3D-modeling means the process of creating a mathematical representation of a 3-dimensional object or shape that consists of polygons and vertices. The objects created are called 3D-models. 3d-characters are advanced 3d-models. When creating a 3d-character, all polygons should be square, with four sides and four vertexes. Having triangle polygons is discouraged, especially in the face as they can produce undesired results or unnatural looks when animating the character. (Autodesk 2021.)

Modelling an object happens by adding vertexes and polygons to the model and modifying the shape of the object. The more polygons an 3d-model has, the more rounded and shapelier it can become. 3d-characters generally consist of large amounts of polygons. (Ismo Jakonen 2019.)

Creating a 3d-character begins by creating a normal 3d-object in the viewport of a 3d-modeling program. The most common starting object is the cube which will be bisected or cut in half from the middle, where all polygons of the other half are deleted. A mirror modifier is then added to the object, which will create a mirror object in place of the previously removed half. This mirror object will be updated simultaneously in real time as the cube half is modified, which will make it easier and less time consuming to create a 3d-character, with perfect symmetry. The halved cube should be the size of a head and be human height above the ground as modelling a 3d-character begins from its head. The model should have as little polygons as possible in the beginning, creating only a rough mesh resembling the character. The 3d-character must be in a T-pose or A-pose, where hands and legs are clearly separated from each other. This will prevent vertexes from the main body from being controlled by hand bones when skinning the mesh and decreases time needed to fix Vertex Groups Polygons can be added afterwards to modify the 3d-character in more detail with

3d-modeling tools. The character can be modified either manually moving the vertices to the desired positions or by sculpting. Sculpting can be less time consuming and allows for easier round shapes. Using special modifiers e.g. subdivision surface will increase the overall polygon count of the character, making the mesh smoother. Alternatively, using an object modifier to smooth the shades causes the mesh to look less blocky. (Nanja Kataja 2020.)

Some 3d-modeling programs e.g. Blender have tools to merge adjacent triangular polygons into square polygons called Quads. When the 3d-character mesh is ready, all modifiers must be applied and the vertexes in the middle checked to make sure the original and mirrored halves of the character have merged correctly. When there are no problems with the mesh, the normals of the character must be recalculated outside so the character cannot be seen through when it is used. (Nanja Kataja 2020.)

2.2.2 Texturing

Textures are flat 2-dimensional images that are applied on the surfaces of 3d-objects. Textures add extra details to 3d-characters like colours, scratches, and bumpiness. Textures can be pictures of real-life materials or pictures made manually in graphic design programs e.g. Photoshop. Texturing includes terms like Texture Mapping, Normal Mapping, Bump Mapping, UV-mapping, Transparency Mapping, Shaders and Materials. (Pluralsight 2014.)

To make texturing much easier, it is important to create or mark seams around specific areas of the 3d-characters body. Marking seams happens by selecting all edges around a certain texturable area like the chest in a continuous loop and marking it. The seam will show the edges in a different colour like red or teal. It is important to do this for all areas around the character to create clear areas for the textures to be applied to. It also assists with creating a texture sheet. An example of a seamed character is seen in figure 3. After all areas have been seamed, the areas must be selected and unwrapped one at a time. The unwrapped areas will appear in the UV editor as 2-dimensional groups of polygons that can be dragged above 2-dimensional textures. This process is called UV mapping. (Pluralsight 2014.)

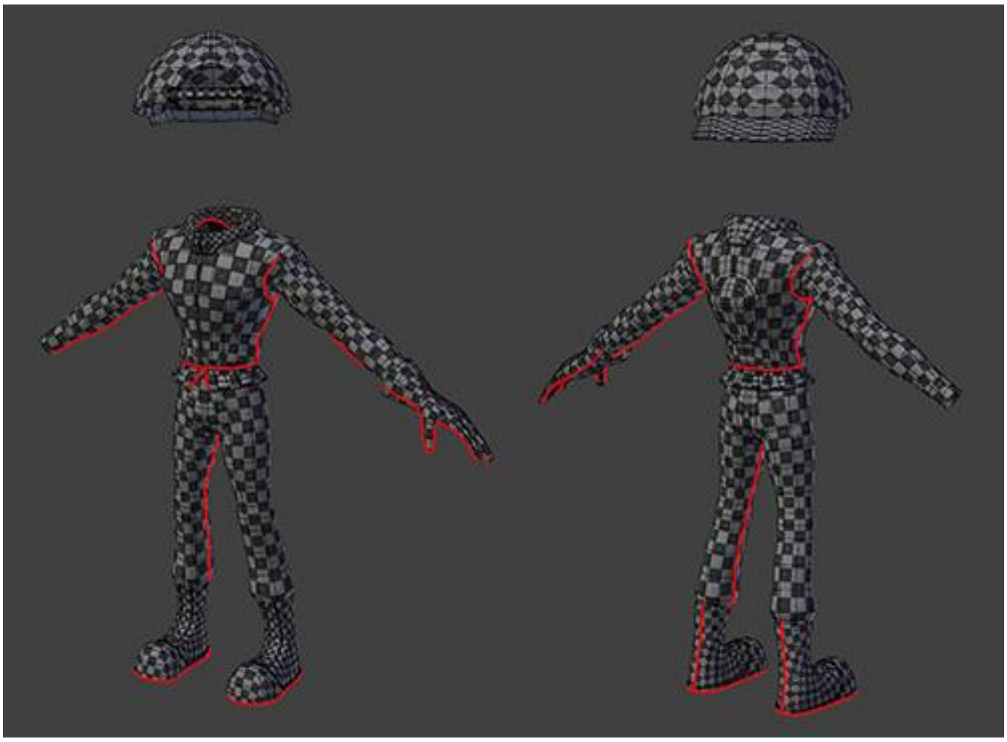

Figure 3. Unwrapped character with Seams marked in red (O’Reilly Media 2021)

Texture mapping adds graphics to polygon objects. Generally, texture maps are either made according to the UV map or the UV map is modified to suit the Texture Map. The UV-mapped unwrapped polygon groups are dragged above the corresponding Texture map in the UV editor. Afterwards a material is created that holds the texture, which is then applied to the model. The Textures apply to the 3d-character according to the mapped textures. An example is shown in figure 4 below. (Pluralsight 2014.)

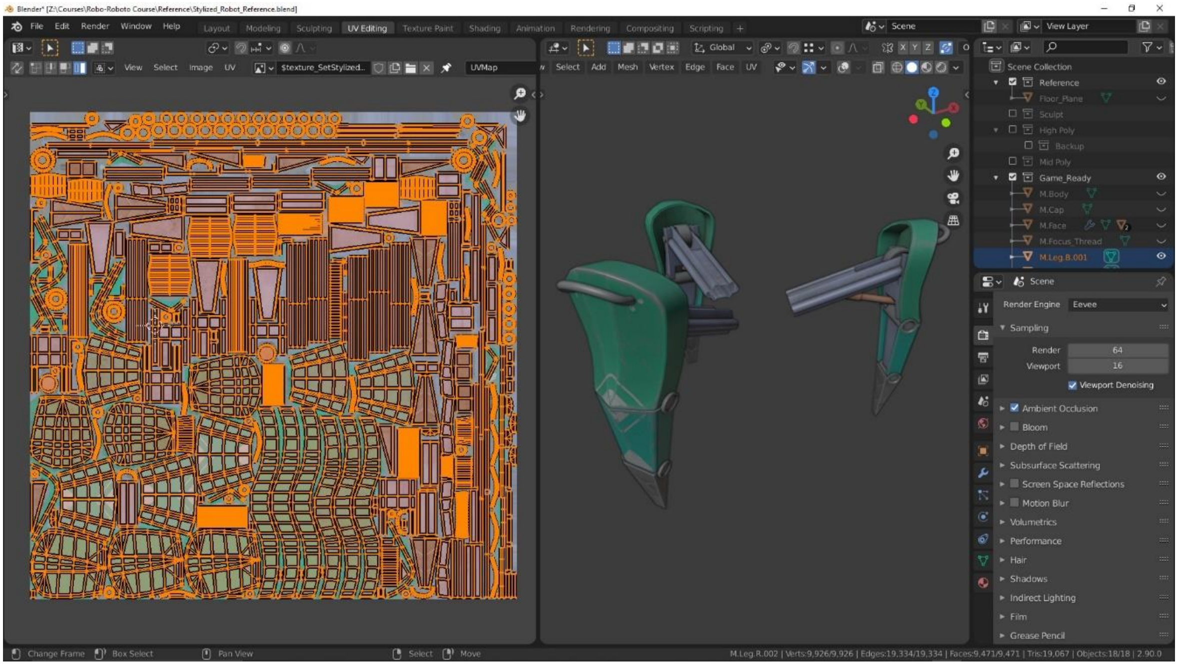

Figure 4. UV-map dragged over textures (flippednormals 2021)

Normal Mapping adds detail to the 3d-character by adding a picture on its surface instead of modelling it. A good example is human six-pack abdomen muscles, a character can have a flat belly modelled on it, while a Normal Map texture with abdominal muscles with shading can be applied on the abdomen area to give the feeling that it has toned muscles modelled on it. Using Normal Maps gives the illusion of detail while drastically decreasing the time needed to spend 3d-modeling and the polygon count. Bump mapping gives the illusion of depth on an object, giving darker areas on the Bump map depth and lighter areas elevation. Transparency mapping is used to create holes in objects using grey scale textures. In Transparency maps, black colour causes object surface to stay visible, while white colour causes the surface to turn transparent. Shaders are items that control values of materials, how light is reflected off material surface, how light is absorbed, the translucency of a material and bump maps. Textures are connected to Shaders to give the 3d-object its look. Materials that textures are attached to have specularity which defines how light is reflected off the surface of the object. Specularity is the reflection of a texture’s light source and defines how shiny the object will look. Specularity defines what material the object looks like it is made of, with metal having high specularity while cement has almost none. (Pluralsight 2014.)

When mappings are finished and material values have reached desirable results, the texture is linked to the material usually by changing the colour option to image texture. The desired texture is chosen to give the material a texture on its surface. The texture is then assigned to selected polygons in edit mode. (Pluralsight 2014.)

2.3 Rigging

Rigging is a general term used for adding controls to 3d-objects. Rigging refers to the process of creating a bone structure of interconnected digital bones. This bone structure called Armature is used to manipulate the 3d-character like a puppet for animations. Rigging an object saves a lot of time compared to animating a 3d-character without one. A rig on a character is also mandatory for using them in simulations and videogames. (Josh Petty.)

The Armature is constructed on the 3d-character representing a real skeletal structure meaning groups of head bones, shoulder bones, back bones, spine, pelvis bones, leg bones, arm bones, finger bones and sometimes even toe bones as shown in figure 5. The skeleton must be constructed in a hierarchical order, where each bone is in a parent/child relationship with each other, which also simplifies animation processes. The goal is to make animations mimic reality as accurately as possible, for example if a shoulder bone is moved, then its children forearm, hand, palm, and finger bones move as well. Bones can be transformed meaning their location, position and scale can be changed, and recording these changes on a timeline using keyframes creates animations. Creating a basic Armature from scratch takes hours, while a comprehensive one can take days. (Josh Petty.)

Some 3d-character models share the same skeletal structures, meaning rigs can be copied and added for use in-between different 3d-characters. Animations can be copied in this way as well. Some bones need additional work placed into them for them to function properly in animations after they have been placed. (Josh Petty.)

Rigs on 3d-characters often have Inverse kinematics added to them, which will reverse the default Forward Kinematics on the bones. Inverse Kinematics are most often used in limb bones like arm- and legbones, which will keep the bones pointing in the right direction and helping the animator achieve more realistic movements more easily. Bones also use constraints, which are restrictions to their movement that prevent them from moving in unwanted directions. Rigging gives the advantage of easy control over deformation of the 3d-model, but it is difficult to animate surface details and will take a lot of time. Especially when creating facial animations, it is better to use shape keys to animate surface deformations instead. (Luis Bermudez 2017.)

Figure 5. 3d-character with an armature (Picture: Henrik Wiiala)

3D-modeling software e.g. 3DS Max and Maya are industry standard level software for rigging and animating 3d-characters. Rigging and animation follow similar workflows, so rigging in free 3d-modeling programs like Blender works without big problems. (Josh Petty.)

2.3.1 Skinning

The process of linking the Armature to the 3d-characters mesh it should deform and transform is called Skinning. Every vertex should be under the jurisdiction of a bone. Two main Skinning types exist. Type 1 is parenting and constraining objects to bones, and Type 2 is using Armature Modifier on the entire mesh. Type 1 causes child bones and their vertexes to be transformed when parent bones are transformed. Children bones are not deformed using this method. Type 2 can use the Armature to control child objects of the 3d-character, where all child objects get the Armature modifier. This is the only way to truly deform the geometry of the 3d-character. (Blender Foundation 2021c.)

When Skinning a 3d-character, always select the character mesh or child objects before the Armature depending on which Skinning type is used. This will make sure the 3d-character becomes a child of the Armature. In Blender, the Skinning menu has all the Skinning options, and rig generation is found in Object Data Panel. The Set Parent To pop-up menu has four options. Armature Deform Parent, which is used for Skinning Type 2, with Empty Groups, with Automatic Weights and with Envelope Weights. Skinning creates Vertex Groups for the vertexes around Bones and are named the same as the Bone that governs the Vertex Group. (Nanja Kataja 2020.)

Skinning with Empty Groups creates empty Vertex Groups that do not have weights assigned to them, meaning vertexes must be manually assigned to each group. Vertex Groups are only created for deforming bones. (Nanja Kataja 2020.)

Skinning with Automatic Weights creates Vertex Groups filled with vertexes. The program calculates how many vertexes around a particular bone should be assigned to its jurisdiction and creates a Vertex Group based on it. This is the most common and easiest Skinning method but can cause problems especially if the 3d-character was not in A-pose when the Skinning was made. May require manual fixes to Vertex Groups. (Nanja Kataja 2020.)

Envelope Weights is like Automatic Weights but the influence of bones on vertexes is calculated based on Bone Envelopes Settings, meaning weight will be assigned to each vertex depending on its distance from the bone. (Blender Foundation 2021c.)

Despite the Skinning method used, it is important to make sure all vertexes have been applied to the correct bones to avoid incorrect transformations. (Nanja Kataja 2020.)

2.3.2 Weight Paint

Vertex Groups hold vertexes which have weight. All vertexes have different levels of weight, which is the level of influence a bone has over vertexes in the Vertex Group it corresponds to. Weight is mainly used for rigging meshed, but can also be used for Shape Keys, particle emission, hair density and modifiers. Weight painting is an easy way to control, change and add weight information to Vertex Groups. (Blender Foundation 2021d.)

Weight painting happens in Weight Painting mode while having the desired mesh, in this case a 3d-character, selected. Weight painting happens by using the brushes to paint the vertexes of an active Vertex Group into different colours of weight. Weight painting uses a Weighting Colour Code system and values from 0 to 1 to describe weight. The weight system uses cold colours or blue for low values near 0 and warm colours of red near value 1 while everything in between is shown in rainbow colours. How high a value is, decides how much weight a vertex has. Weighting Colour Code system is shown in the figure 6 below. Blender also has a special visual notation as an option for unreferenced vertexes that are shown in black colour. This is effective for finding weighting errors. Picture of the visual notation is shown below in figure 7. (Blender Foundation 2021d.)

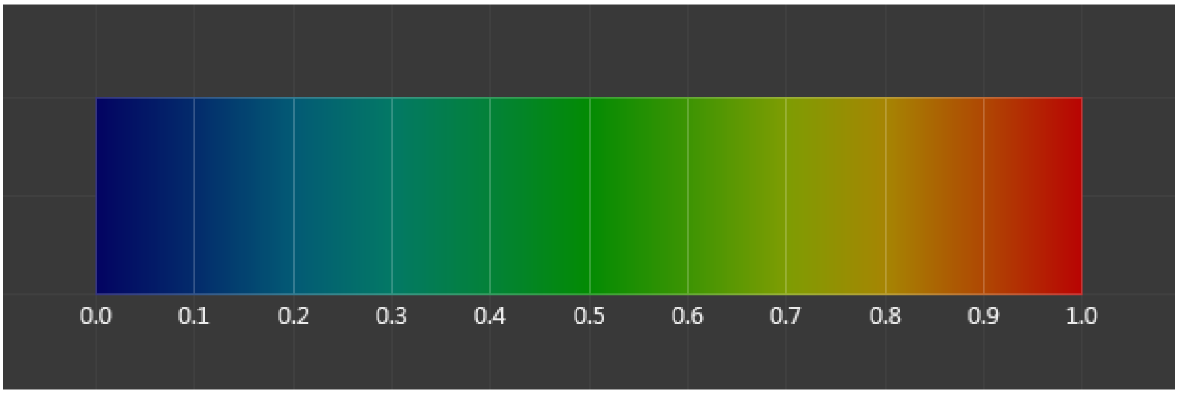

Figure 6. Weighting Colour Code system (Blender Foundation 2021)

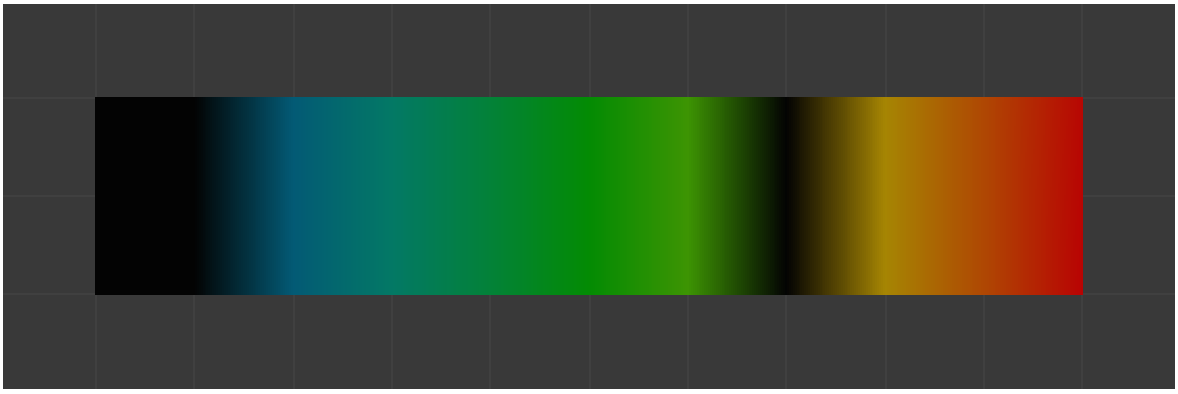

Figure 7. Visual Notation (Blender Foundation 2021)

For deformations, weights should be normalized, meaning all deforming weights assigned to a single vertex add up to 1. The Armature modifier automatically normalizes weights. Normalized weights have advantages e.g. use of the tools designed for them and understanding the influence of the current group does not require knowing weights in other groups on the same vertex. The tools for working with normalized weights include Normalize All, Auto Normalize, Vertex Group Locking and Multi-Paint. Normalize All tool normalizes all existing weights. Auto Normalize maintains normalization automatically when weight painting. Vertex Group Lock locks any Vertex Group to prevent making changes to them, which prevents accidental changes made to them. Multi-Paint allows treating multiple selected bones as if they were the same bone. (Blender Foundation 2021d.)

Weight painting is used to make 3d-character movements look more fluid and natural. For example, when a bone is moved, the vertexes around the bone should move or stretch slightly as well to create an illusion of having flexible skin. Using weight painting to paint a low level of weight around a joint will achieve this. It is important to keep in mind that if weight painting vertexes outside the currently selected Vertex Group, they will be added into the current group. figure 8 shows a character with Weight Paint (Blender Foundation 2021e.)

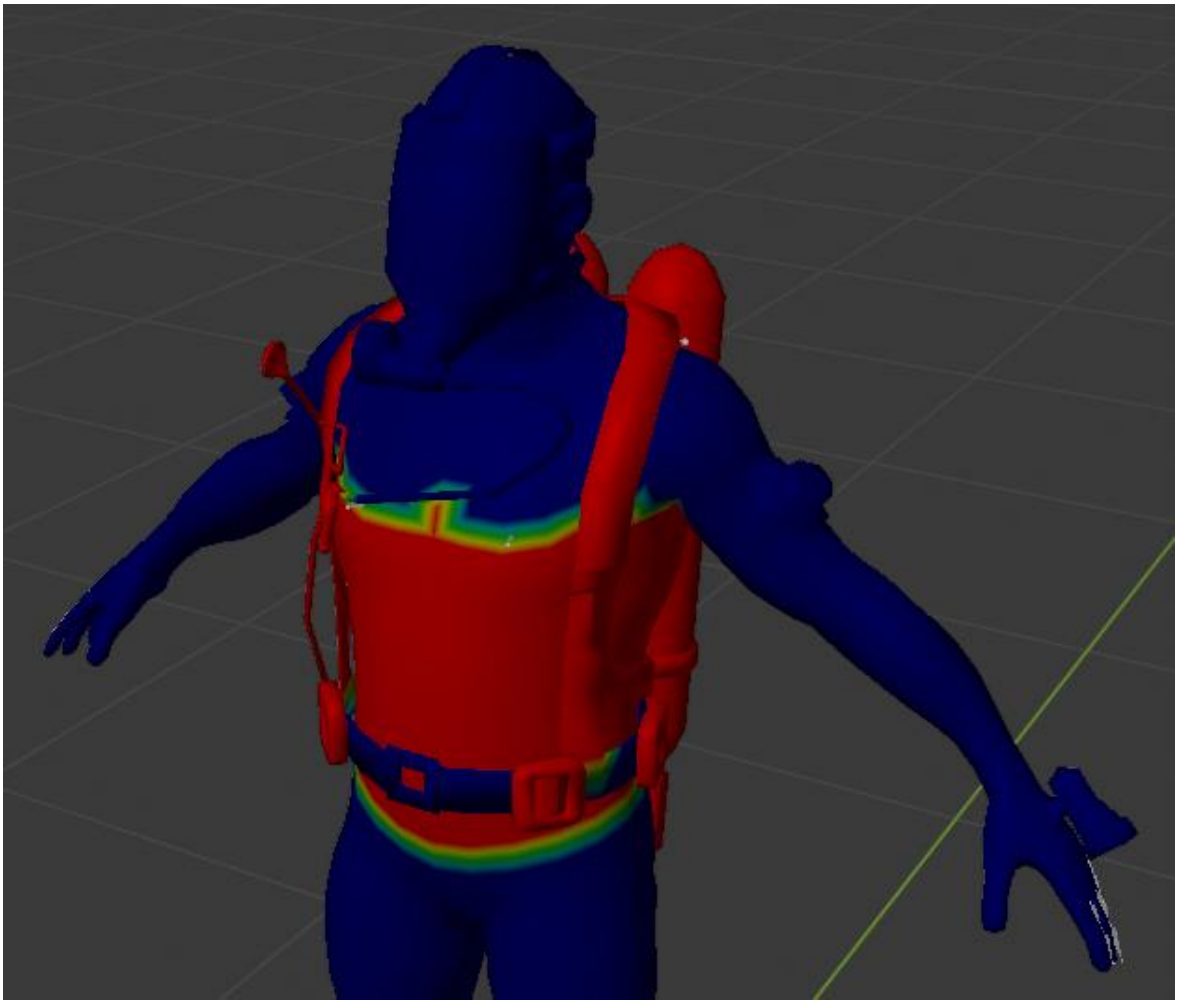

Figure 8. 3D-character with weight. (Picture: Henrik Wiiala)

3 3D-character animation

3.1 3D-Animation

3D-character animation is the automatic movement or transformation of a 3-dimensional character in space and time. The movement of a 3d-character requires 3d-modeling and animation software and smart programs, a 3d-character mesh with rigged bones, pre-planning and imagination of how the 3d-character should move and what natural forces e.g. gravity, friction and resistance affect the 3d-character. A 3d-character should move as the viewer would imagine. The 3d-character's appearance should affect its animations, how it walks, its facial expressions and interactions with the surroundings. An example of a 3d-character is found in figure 9 below. (Artland 2020a.)

Figure 9. 3d-character in Blender (Picture: Henrik Wiiala)

The four methods of character animations are keyframe animations, trajectory animations, animation in dynamic environments and motion capture animations. Keyframe animations are the most common way to animate 3d-characters, where transformation states of location, rotation and scale are saved to a keyframe located on a frame of the timeline, see figure 10. A timeline frame can have multiple keyframes. The 3d-character will transform its location, rotation, and scale states from one keyframe to the next as the timeline proceeds, creating an animation. Trajectory animations have a 3d-character or object follow a path where the starting and ending points are defined. The path can be in any shape or form, and the character can have other animations active simultaneously. Animation in dynamic environments is the result of physics affecting the 3d-character. Cloth physics cause clothes to flutter in the wind or water making fur to stick to skin. Dynamic animations require a lot of processing power from the computer. Motion capture animations use a suit with sensors to record the movements of a real person, creating a 3D skeleton rig and keyframes from the recorded movements that can be imported to 3d-modeling and animating software. The animation takes physics into account, so it is almost ready to use immediately. (Artland 2020b.)

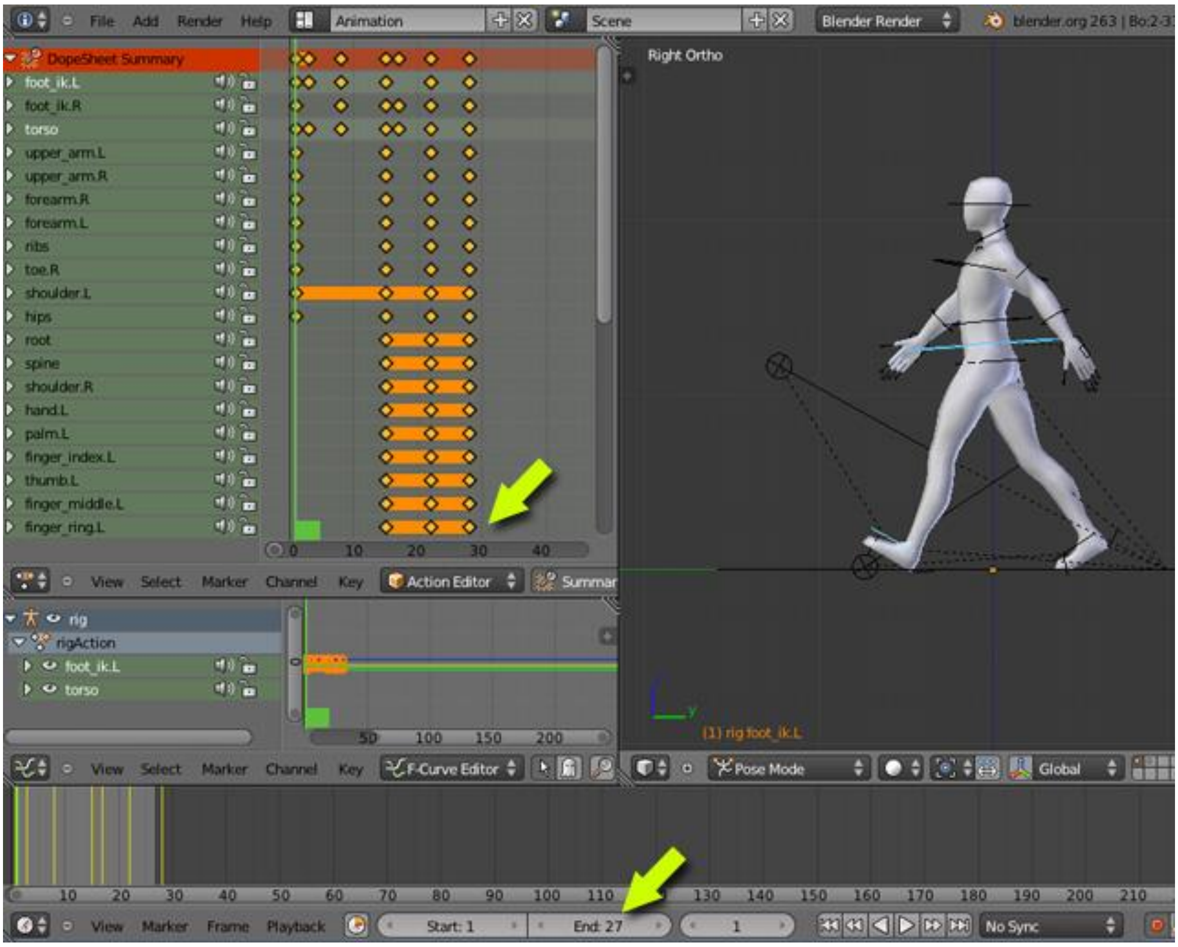

Figure 10. 3d-character in a walk pose with Keyframes (Opus Web Design 2014)

Facial animations are used for creating facial expressions. Facial animations are made by either manually moving rigged bones or using shape keys to ease the transformation of facial vertexes in expressions, with each expression and individual facial movements e.g. batting eyes or having wrinkles while smiling having its own shape key and value on a slider. The slider is used to change the expression easily on a face during animations. The expressions have their own keyframes. A human has 42 individual facial muscles and creating an animation to emulate all of them can be difficult to accomplish by manually animating a face. Using Motion Capture technologies makes it much easier. An example of facial animations with different techniques in figure 11 below. (Karan Shah 2014.)

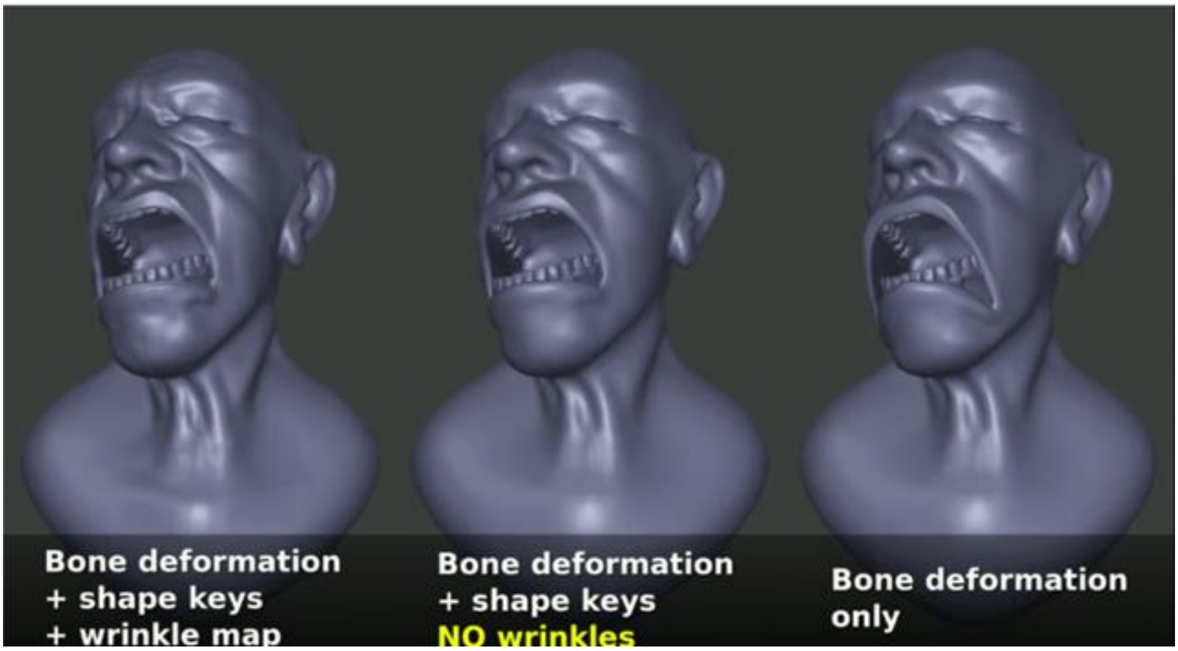

Figure 11. 3D facial expressions (createcg 2015)

3.1.1 Keyframes

A keyframe is a marker of time that stores for example the location, rotation, and scale values of a property in 3d-modeling and animating programs. Keyframes are interpolated, meaning the exact position for a 3d-object will be calculated for every frame on the timeline between keyframes by the 3d-modeling program based on the interpolating method chosen. Keyframe interpolation is represented by animation curves or F-curves that are controlled in the curve editor. In the curve editor, the X-axis equals time, and the Y-axis represents the value of the property. The keyframes are shown as points on the curve editor, and interpolation is controlled by the user with different interpolation modes. F-curves are edited by transforming the locations of keyframes and modifiers can be added to F-curves for various effects. (Blender Foundation 2021a.)

Some editors like Blender, show different keyframe types with different colours. The scale and colour of keyframes differ depending on its qualities and state, with an unselected keyframe being lighter in colour compared to a selected one. Normal keyframes are white when unselected and yellow when selected. Breakdown keyframes, the transition between keyframes is light blue and cyan. Moving Hold keyframe adds a small amount of motion around a holding pose and is dark grey and orange. An extreme state keyframe is pink and light red. A jitter is a filler keyframe or used for baking and is green. Figure 12 shows different unselected and selected keyframe colours. (Blender Foundation 2021a.)

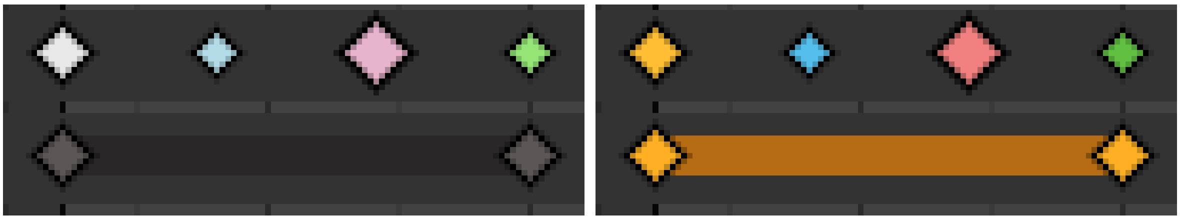

Figure 12. Keyframe Colours (Blender Foundation 2021)

3.1.2 Curve editor

Interpolation mode allows the user to specify how each curve from one keyframe to the next is interpolated. There are 3 modes, Constant, linear and Bezier. Constant means no interpolation. The curve only holds the values of the last keyframe. Linear interpolation creates a non-continuous, zig-zagging line with straight segments. Bezier is the default mode with round, smooth curves for smooth animations. Some F-curves can only take discrete values where they are shown as constant interpolated. Curve shapes are shown in figure 13. (Blender Foundation 2021b.)

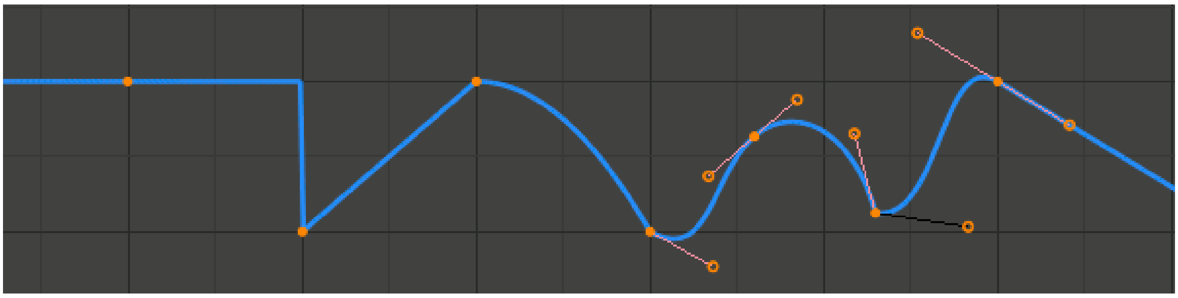

Figure 13. Curve Shapes (Blender Foundation 2021)

The usage of different curve shapes for animations, how one keyframe transitions to another is called easing. Easing achieves different effects for animations, e.g. more fluid, natural and snappy movements, and reduces the amount of manual work needed for tweaking and inserting keyframes. Correct use of easing causes dynamic effects like imitating physics, fake ball-bouncing, springing movements and speed deceleration. Easing Type controls which end of the segment between two keyframes the easing applies to. The four types of easing are: Automatic Easing, Ease In, Ease Out, Ease In Out. Automatic Easing uses the easing type most expected for the situation. Ease In causes effects to build up to the next keyframe. Ease Out causes effects to fade out from the first keyframe. Ease In Out causes the effect to occur on both ends of the segment. The dynamic effects of easing include Elastic, Amplitude, Period, Bounce and Back. Elastic effect is a decaying sine wave, like holding a ruler horizontally half-outside a tables edge, bending the other half and releasing it. Amplitude controls how strongly the curve oscillates and diverges from the basic curve shape. Value 0.0 means no oscillation. Period effect controls the frequency of oscillations, with high values causing dense oscillations. Bounce-effect causes an exponentially decaying parabolic bounce like a bouncing ball. Back effect causes overshooting past the next keyframe, e.g. wind-up anticipation. It also controls the size and direction of the overshooting. (Blender Foundation 2021b.)

Extrapolation mode controls the curve behaviour between the last and first keyframes, with 2 basic modes: Constant and Linear. Constant is the default mode, where curves after the last and before first keyframe have a constant value. Linear mode has straight lines at the ends of the curves. (Blender Foundation 2021b.)

Using Bezier-interpolated curves allows for choosing the handle type for controlling the curve slope by the control points. Each control point can have a different handle type within the same curve. Three automatic handle types exist: Automatic, Auto Clamped and Vector, with two manual ones: Aligned and Free. Automatic handles produce automatically chosen handle positions for smooth curves. Auto Clamped mode prevents overshooting and changes in curve directions between keyframes, keeping the curves in S-shapes. Vector handles create automatic interpolation between keyframes, where curve-segments stay linear when keyframes are moved. When control points are moved, the handle type switches to Free type. Free handles allow for completely independent movement, with sharp changes in curve direction. Aligned handles have two handles at the curve point that always point in the opposite directions of each other, resulting in the curve being smooth at the control point. (Blender Foundation 2021b.)

3.1.3 Facial animation

Facial animations mean the movement of bones and vertexes on a 3d-characters face to create expressions and nuances. Facial animations are made by moving the facial bones and saving the keyframes to timeline or editing shape keys and their values during animation via bones or other methods and saving the keyframes. Some programs like 3DS Max use a morpher modifier instead of shape keys, while others like Maya call shape keys ”Blend Shapes”. (Nanja Kataja 2020.)

To create shape keys, the 3d-character must be selected while pressing the add button for shape keys in the Object Data Properties panel. The first shape key created will be the base state for the 3d-characters face shape, called Basis. Basis should not be modified at all. The subsequent shape keys created will control facial movement and should be divided into 3 vertex group categories, left side, right side, and entire face. Aside from the Basis shape key, new shape keys can be modified. Having a shape key selected, the face can be modified in edit mode or through Sculpting to make expressions e.g. closing eyes or smiling. The modifications only apply for the selected Shape Key. The Value slider controls the difference in facial expressions between the selected Shape key and Basis shape key. If the Basis Shape Key has the 3d-characters eyes opened, and Shape Key 1 has eyes closed, then modifying the value of the Value slider of Shape Key 1 determines how open the 3d-characters eyes are. Value 1.000 would mean the eyes are completely closed, value 0.500 means eyes are half-closed and value 0.000 means eyes are completely open. An example can be seen in figure 14. Vertex groups are created by pressing the add button for Vertex Groups in Object Data Properties panel. The vertexes of the face should be allocated to the 3 vertex groups in edit mode, where the desired vertexes are selected and assigned to their vertex groups. Starting from middle of the character, all vertexes on the left side of the face must be selected and assigned to the Left Side vertex group. With the same logic, the vertexes on right side of the face must be assigned. All the vertexes of the face will be assigned to the Whole Face vertex group. Subsequent Shape Keys can be selected and assigned to vertex groups so changes only affect the desired part of the face. (THE LUWIZ ART 2019.)

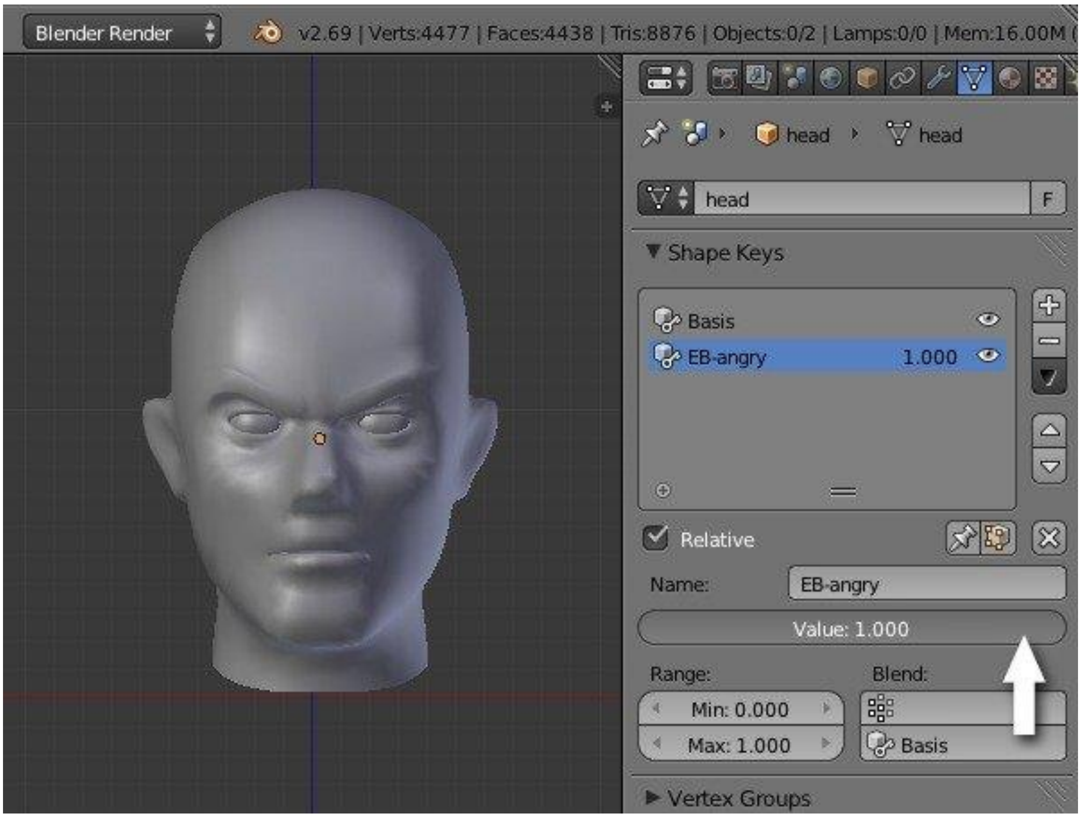

Figure 14. Shape Key with value 1 for angry expression (Karan Shah 2014)

Adding keyframes during animations is done by right clicking the Value slider of a Shape key and selecting Add Keyframe. Alternatively, a rig bone driver can be added by right clicking the Value Slider, adding a new Driver, and selecting the bone to be a driver that can be moved to change the Slider value during animations. (FruitZeus 2021.)

Animating a face with bones requires a rig skeleton with facial bones on the 3d-character. To animate with bones, the skeleton must be selected in the Animation view and entered Pose Mode. Facial animations are generally made in Action editor, with each expression a separate action. The starting frame of the animation in the timeline should have the keyframes of an expressionless face. Keyframes can be inserted with the Insert Keyframe command ”I” or right clicking the screen and choosing the option with the desired bones selected. Facial animations are created with subsequent bone movements and keyframe additions at different frames of the timeline. Having auto-keying active will modify or add a keyframe for a bone that is moved to the current timeline frame without manual commands. Saving the project will save all changes to the actions. (Nanja Kataja 2020.)

Aside from the 3d-modeling software, other external programs can be used to create facial animations. When creating facial animations using external programs, it is important to choose the correct program as some are made purely for animating faces for videos, while others can export the animations and even characters made from pictures in the program to 3d-modeling software e.g. Blender where they can be further modified. (CrazyTalk8 2021.)

Such external programs include facial pre-sets, ready-made lip movements for every syllable, easy movement of facial muscles and eyebrows and live face -movement recording for copying the facial movement of a real person for the 3d-character. Some programs can even be used as add-ons for 3d-modeling software. Facial animations can also be made with raw Motion Capture data using suits. (Artstation Magazine 2021.)

3.2 Motion capture

Motion Capture or MoCap is the process of digitally recording the movements of live people. For 3d-character animations and visual effects, capturing motion means recording the actions of actors. If MoCap includes full body movements, fingers and face or captures subtle expressions and nuances, it is called performance capture. Motion Capture data is the information of the recorded movements saved to a virtual environment. Motion can be captured in any environment if the equipment can withstand the stress. The equipment consists of hardware and software. The hardware includes suits, cameras and sensors that sends data to the software. The software are various programs that record, monitor and review Motion Capture data. The raw data can be used to create 3d-character models and realistic animations that can be exported to 3d-modeling programs to be modified further off to enhance already existing animations or 3d-models as shown in figure 15. Some animations such as sitting is easier made by using Motion Capture than by manual animation. MoCap can enhance Virtual Reality -experiences by adding full-body motion sensor data of motion capture suits to the visor and handheld controllers. (Xsens 2021.)

LAB-University has the ability to provide MoCap suits for use. The institution specifically uses Optitrack and Neuron equipment that are specialised in capturing body movements.. (Ismo Jakonen 2021.)

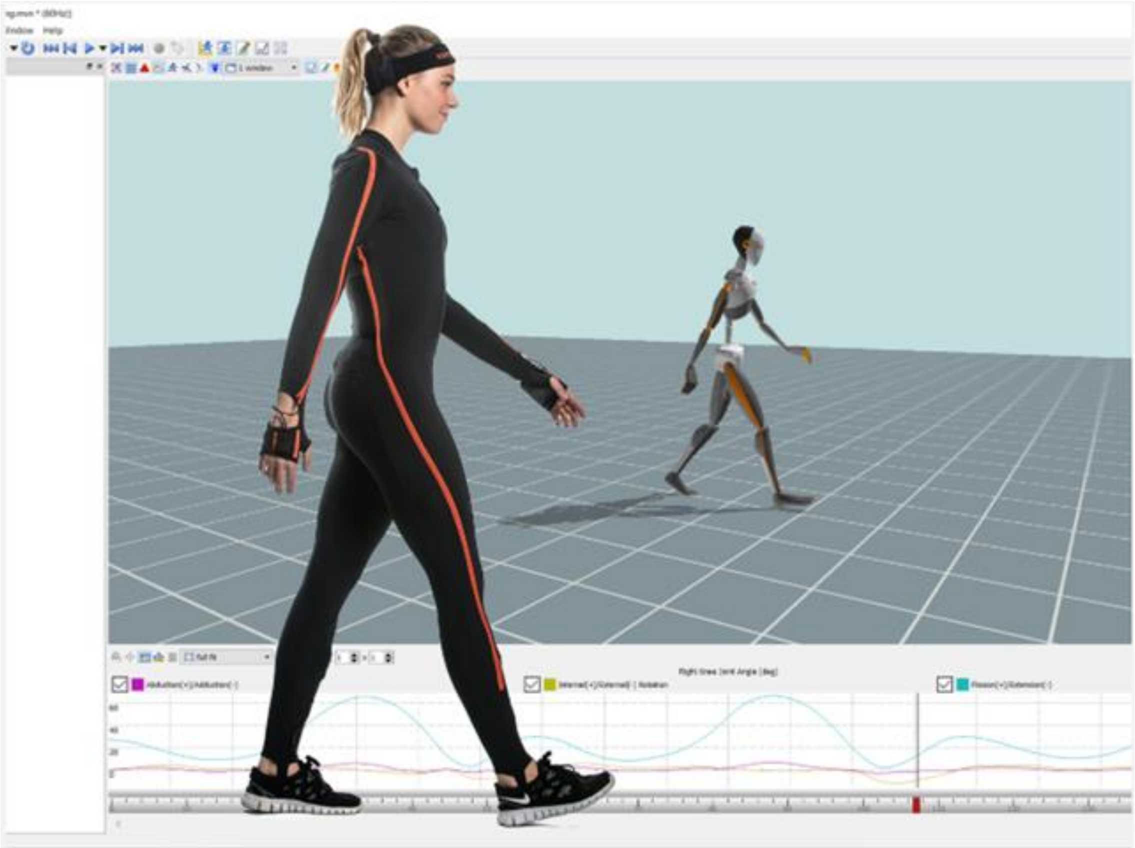

Figure 15. Model and animation from MoCap data (Xsens 2021)

4 Blender animation tools

4.1 Tools

The primary tools for making animations in Blender are keyframes. There are three main ways to animate characters. These ways include moving the whole object, deforming the object and inherited animation. Moving the object means changing their position, size or orientation in time, therefore creating movement animations. Deforming the object means animating the vertexes or control points of the character and Inherited animation means causing the character to follow or move based on the movements of another object. (Blender Foundation 2021e.)

In Blender, animation can be made in Layout, Animation and Composition windows. The Animation window is the most specialised and holds all the tools for all animating. Animating 3d-characters is best made in the Animation window. The Animation window includes the Timeline, a selection of different editor types, for example the Graph Editor and Driver editor and a dropdown for different modes e.g. Dope Sheet, Action Editor, and Shape Key Editor, including others. (Nanja Kataja 2020.)

The Dope Sheet mode allows modification of all existing keyframes in the Blender scene, and has View, Select, Marker, Channel, and Key dropdown menus for effective handling of keyframes and F-Curves. (Nanja Kataja 2020.)

Action Editor is for editing the animations of currently selected object(s), and this is the mode that is most used for creating animations for 3d-characters. Every animation will be saved as a separate action for the character’s skeleton. These actions can be re-used for other character’s as well. (Nanja Kataja 2020.)

Shape Key Editor is used to edit the keyframes for the currently selected 3d-character’s Shape Keys and using them to create animations. (Nanja Kataja 2020.)

The mode menu also includes other modes e.g. Grease Pencil that edits timings for all grease pencil sketches in the file, Mask that edits timings for Mask Editor splines and Cache File that edits timings for Cache File data-blocks. (Nanja Kataja 2020.)

4.1.1 Action Editor

The main way to create animations has been to save character poses using keyframes on the Timeline, which will then alternate between saved character poses as the timeline advances forward from one keyframe to the next, resulting in an animation. Another technique that has surfaced recently is Motion Capture animation directly recording the movement of a person and converting it to a keyframe animation in Blender, where it can be modified, and movement distortion can be reduced. (Nanja Kataja 2020.)

When creating animations, it is important to separate different animations into named actions. Having actions makes it easier to use them in conjunction to each other in simulations, it also makes it possible to copy animations and then modify them into different ones to either save time or to create transitional animations. A transitional animation is used in the middle of transitioning from one animation to another, to make it look more natural. Dope sheet can be used to keyframe and animate objects that are not part of the character rig but should still be present in the animation while Shape Key Editor should be used to animate faces by saving Shape Key values as keyframes. (Nanja Kataja 2020.)

4.1.2 Techniques

As an animation is being created, using F-Curves in clever ways to modify keyframes creates more flexible joint movement without specifically creating new keyframes for the effects. There exist web pages that clearly illustrate all the F-Curve techniques and how to use them for varying effects in Blender. Correct use of transform pivot point, using the X, Y and Z directions to move and rotate bones in different ways and using Frame options to Transform, Snap, Mirror or even duplicating Keyframes are techniques that professional animators use. This not only gives the animation a more natural feel but also decreases the need to fix incorrect poses and saves a lot of time. Another technique is using MoCap movement data and converting it into Keyframes and Actions, using the Dope Sheet to remove the distortion to quickly create a new animation. This MoCap animation technique also works for creating realistic facial animations quickly. (Nanja Kataja 2020.)

5 Case

5.1 Background

The Cross-border safety, accident prevention and management project is an international Finnish-Russian collaboration that aims to promote border safety, security and management by enhancing the safety knowledge and attitude of individuals crossing the border and improving the performance and cooperation in rescue operations on both Finnish and Russian sides. Another aim of the project is to test the latest technologies and equipment for rescue situations and improve the cooperation model for rescue professionals. The project also brings together both the direct developers and end-users in joint activities of dissemination and benchmarking of results to guarantee the goal of producing practical solutions is met. (Jaana Loipponen 2021.)

The purpose of CB-Safe is to create a training simulation in a Virtual Reality training and education -environment to educate professional leaders of rescue operations from the Finnish and Russian Rescue Departments. The objective is to allow the rescue operation leaders to learn leadership and decision-making skills in a virtual real-time rescue operation where decisions have consequences that can lead to success or complications and failure of the operation. Each rescue simulation will hold a set amount of players ranging from two to ten that will communicate with each other to successfully complete the rescue mission they are assigned to. The goal is to also be able to complete different rescue missions at the same time with the Russian Rescue Department. (Jaana Loipponen 2021.)

The focus areas of the project are the five Finnish-Russian border-crossing points in South-Eastern Finland called Saimaa Canal, Imatra, Vainikkala, Nuijamaa and Vaalimaa. The border points together cover the three transportation methods for border-crossing, roads, trainways and waterways, each of which will be the main venue of a rescue operation simulation. (Jevgeni Anttonen 2021.)

5.1.1 Character creation

The case uses an UMA 2, short for Unity Multipurpose Avatar for the humanoid 3d-character models. The UMA models are all customizable and have their limbs clearly separate into their own categories which makes them easy to use not only for VR player character animations but as normal 3d-characters as well. It also allows for the merging of meshes and textures and makes it easy for them to use external objects. The models are free to download from Unity asset store and 3d-modeling software used for modifying them is Blender v2.8 or above. To modify the UMA model, it must be exported from Unity using the built-in

FBX exporter as an .fbx file. The .fbx file is opened in Blender using the Import function. The imported UMA model can be twisted and deformed at the beginning as shown in figure 16. This is fixed by selecting the Armature, going into Pose Mode, selecting all bones again and resetting bone rotation, position, and scale. The 3d-model should return to its base form. If the model is sideways, return to object mode, select the 3d-model only and rotate it to match the direction of the Armature. In the worst case, the Armature itself may stay twisted despite the resets, which means it needs to be completely replaced.

When the 3d-model is selected and inspected in edit mode, the model may be filled with triangular polygons as shown in picture x, that are bad for optimization and animations as they cause the model to require twice the effort to run compared to having square polygons and may cause the mesh to deform in unnatural ways during animations. The triangular polygons must be turned into square polygons, and this is done by selecting all polygons in Edit Mode, selecting the Face drop-down menu, and turning all Tris to Quads.

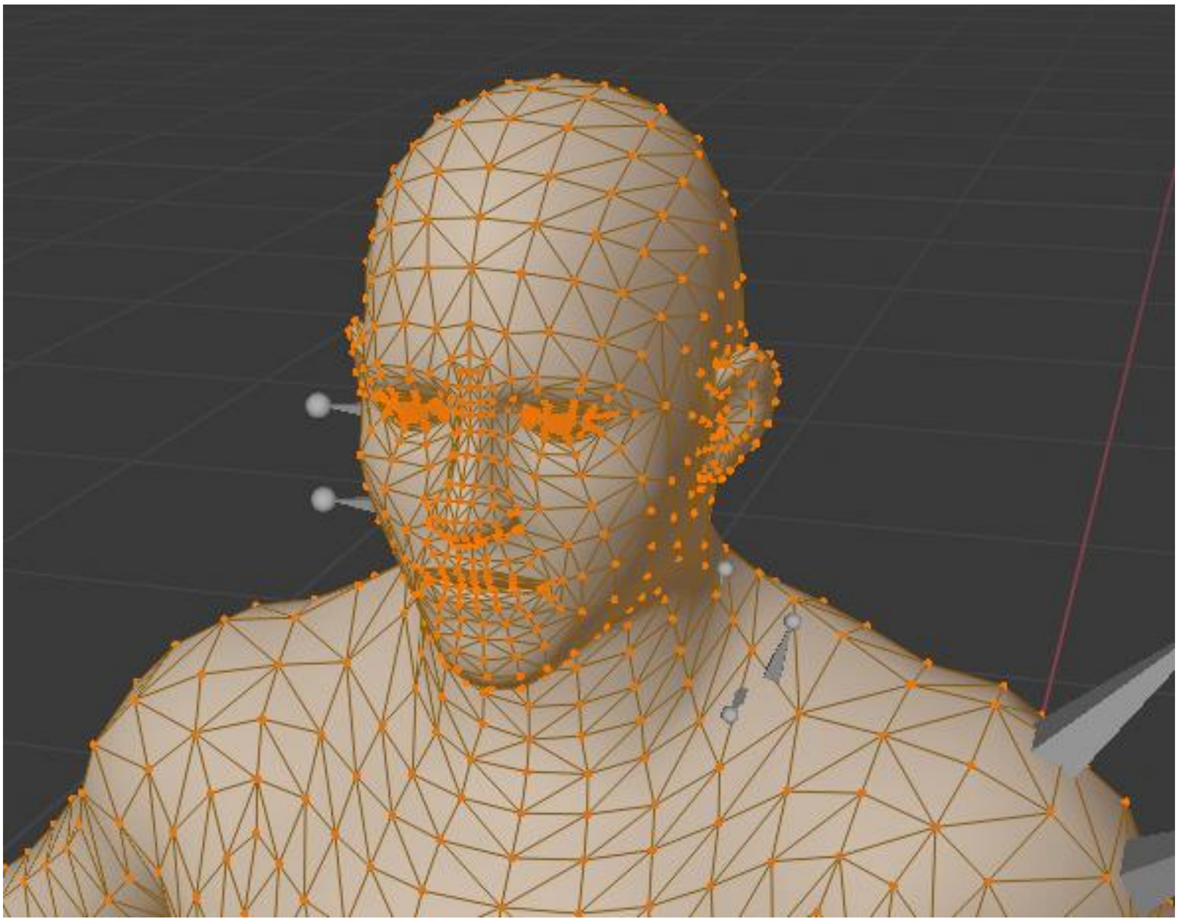

Figure 16. Triangular polygons. (Picture: Henrik Wiiala)

The first step of creating a 3d-character for CB-Safe is to know the purpose of the model. The purpose is tied to the job of the rescue personnel the model is depicting, and it will define what reference material will be sought, what the 3d-character is going to look like and what animations it will have. After the purpose is known, either request the Rescue Department contact person for reference material or find it from their webpage pictures, videos or elsewhere on the internet. Good enough reference material can even be used directly as textures.

The second step is to create the outer looks of the model. Clothes and the equipment on the character are modelled to be part of the character itself when not using cloth physics, while materials and textures can be used as a substitute in some cases to create the illusion of having clothing. If the character needs actual clothing, it is modelled above the character's skin by copying and scaling the vertexes to go with the character's body shape, while the vertexes under the clothes that will not show at any point will be deleted to decrease the polygon count. Using this method requires skinning the character again, either by using the option on the Armature or manually assigning the new vertexes into the corresponding Vertex Groups. If creating the illusion of having clothes, it can be done by marking seams and assigning materials and textures on the vertexes that make up seamed areas. This is a good way to create skin-tight clothes, low level-of-detail models and saving polygons. These two ways can also be mixed, using both materials, textures, and actual modelling to create a whole. Creating different levels of detail can be made by creating a low-polygon model first and then saving it as a new project, then modifying the model using modifiers and other methods into a better level-of-detail version. Shade Smooth option can be used to create the illusion of round shapes without using modifiers. The figure 17 below shows the difference between having modelled clothes and having materials as clothes.

Figure 17. Modelled clothes vs Materials as clothes. (Picture: Henrik Wiiala)

Creating equipment on the model is made in the same way as clothes, being in edit mode and adding a new mesh to be part of the 3d-character and modifying it into the shape of the equipment needed.

All the limbs of the model, chest, abdomen, back, legs, arms, head, and other areas that will have textures must be marked as separate seams, loops that clearly define areas using the Mark Seam function, and then unwrapped for easier texturing. Textures can be found as pictures on the internet or be made by oneself. It is a generally accepted way to use an external picture handling software like Photoshop to modify the textures into a suitable form such as a texture sheet for easier usage in Blender, however this is not always necessary. Multiple texture pictures can be used, one for each or multiple seams.

The third step is to check all vertexes belong to their correct Vertex Groups and applying or modifying any necessary weight paint onto the character. Selecting the character mesh and going to the Weight Paint -mode gives access to Weight Paint tools. Going to Object Data Properties and selecting any Vertex Group shows how much weight a group has. Skinning the Armature usually automatically applies an acceptable amount of weight paint to every Vertex Group.

The fourth step is creating the needed animations; however, they do not need to always be created on the character that is going to use them. In Unity, switching animations on a character is as easy as changing shoes.

5.1.2 Character animation

Before any animation attempts, make sure the bones can be seen from under the 3d-character. This is done by selecting the Armature in Object Mode, selecting Object Data Properties and the Viewport Display dropdown menu, and checking the In Front -checkbox.

In Blender, character animation happens in the Animation view. Every animation must be a separate Action so they can be effectively used in the simulation. Switch from Dope Sheet to Action Editor. Create a new Action by pressing the Create New Action button and name it in accordance with what the animation is going to be e.g. Running, Walking, Swimming Frog or Item Pick Up.

If the animation is a looping animation, the first and last frames, and their F-Curves on the Timeline must have the keyframes for identical character poses. All other keyframes in between should either be inverted character poses of the first and last frames e.g. if first and last frames have the character raise their right leg, then the inverted pose should be the character raising its left leg, or transition poses of moving between the main poses. Just having three or four main poses are not enough to create a fluid animation, it needs many transition poses with F-Curves and other minor body movements to make it a complete natural looking animation. To control F-Curves in Blender animation, set Editor Type to Graph Editor. Interpolation mode, Handle Type, Easing type, Easing and Dynamic Effects can all be chosen from Key dropdown menu. Controlling F-Curves happens in the same way as editing Keyframes, either editing all at the same time or one-by-one for each bone. To return to Action Editor, set Editor Type back to Dope Sheet.

Blender saves the Actions by saving the Project, and the animations can be accessed in Unity by Exporting as an .fbx file from Blender to Unity. The 3d-character models are tested in Unity on a general level, making sure the colors, textures and animations work as they should.

The characters were made as low-polygon level-of-detail models as requested to optimize the running speed of the simulation and make it run more smoothly. Figure 18 shows the end results of two 3d-characters in Unity.

Figure 18. Result of 3d-characters with animations (Picture: Henrik Wiiala)

6 Summary

The intention of the thesis is to explain the use of 3d-character animation in a Virtual Reality environment, explaining VR, 3d-modeling, 3d-animation and their sub-areas on a general level. The Case is to explain the steps to create a complete animated 3d-character with Blender that can be used in a VR-simulation, and the result of testing it in Unity game engine.

The thesis tells of the immersive computer-generated environment called Virtual Reality and how it can be used for simulations and communication, albeit being a still developing technology that has some problems that will be fixed in the future. The use of 3d-animation in a VR-environment needs a 3d-character that consists of a 3d-shape called Mesh, rig skeleton or Armature, materials and textures that has to be animated using Keyframes either manually or using Motion Capture technologies. The Case explains the first design and reference material gathering phase where the 3d-character is designed before the Mesh and animations are modified, the second phase of 3d-modeling, where to get the UMA mesh the simulation needs, how to modify it and how to get textures. The third phase is checking that all vertexes and weights are correctly allocated and fixing if needed. The fourth step is animation using Keyframes. The final step is testing in Unity environment.

It was discovered that Virtual Realities cannot yet run heavy models effectively, which means all 3d-models need to be polygon count -optimized, or so called low-polygon models as the amount of polygons is proportional to the amount of power needed to run them. Models can be highly detailed despite being clunky low-polygon models by clever usage of materials and textures, especially using smoothed shades, texture mapping and normal mapping techniques. Using level-of-detail will allow models to alternate between low-poly and higher detail models based on distance in simulations, decreasing power consumption. Using F-Curve techniques with Keyframes or using Motion Capture is easier and saves time in creating animations.

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