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Creating hair for a 3D character with Autodesk Maya, XGen and RenderMan

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<p>Abstract</p> <p>In this thesis I make hair for a 3D character for a CG animation. I'm using the following softwares: Autodesk Maya, XGen and RenderMan. Maya is the 3D studio I'll be working in from to create the hair till rendering it. With XGen I'll generate and shape the hair strands. I'll animate the hair with Maya's dynamic simulation tools. With RenderMan I'll shade and render the hair. The end result is almost realistic hair in CG animation.</p> <p>My workflow is pretty straightforward. First I explain through my software choices and starting scene. After that, I explain and show the steps, and reasons behind them, of making the hair while creating it. At the end I analyze the result and explain how I would continue the process.</p>	
Keywords	3D, computed simulation, hair simulation, dynamic simulation, Autodesk Maya, RenderMan, XGen

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<p>Tiivistelmä</p> <p>Tässä opinnäytetyössä teen 3D hahmolle hiukset lyhyt animaatioon. Käyttäen ohjelmistoja: Autodesk Maya, XGen ja RenderMan. Maya toimii 3D työtilana hiusten muotoilusta kuvantamiseen. XGen:illä generoin ja muotoilen yksittäiset hiukset. Animoin hiukset dynaamisen simulaation keinoin Mayan työkaluilla. Sävytän ja kuvannan hiukset käyttäen RenderMan:iä. Lopputuloksena on melkein realistiset hiukset tietokoneella tehtyyn animaatioon.</p> <p>Työnkulku on mahdollisimman suoralinjainen. Ensin selitän ohjelmisto valintani, sitten aloitus tiedostoon jo asettamani asetukset ja elementit. Tämän jälkeen siirryn hiusten tekoon ja työvaiheiden selittämiseen. Lopuksi pohdin lopputulosta ja kuinka parantaisin sitä.</p>	
Keywords	3D, tietokonesimulaatio, hius simulaatio, dynaaminen simulaatio, Autodesk Maya, RenderMan, XGen

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1. Introduction

"Hair is known to be one of the most complicated challenges in CG animation. In reality, the human head has over 100 000 strands of hair. Each strand is very thin and highly deformable and creates constant collisions both among the hair and between the hair and the body. Therefore actually computing these calculations of how the hair is interacting with each other become really complicated to do on the computer. Also, hair has really specific shapes and details that it tries to hold on to. Whether the hair is curly, or wavy, or straight, it has to be considered in the base simulation." says Kelly Ward, a senior software engineer at Walt Disney Animation Studios. (Tangle Hair Rig Demo 2013.) She spent six years writing programs to make Rapunzel's unnaturally long hair to move perfectly in movie Tangled. (Wikipedia 2017a.)

During the making of this thesis, I create, and document my process of making, a hair simulation. I will create a long hairstyle that moves naturally with my character. I start with an animated character with a set of long base curves, for hair, already modeled in the scene, and end up rendering out needed hair layer passes of animated hair. The general style is cartoony, so ultra-realism in hair is not needed. The hair still needs to have believable look and movement.

The hair rig will be much simpler and uncontrollable than in the movie Tangled. In Tangled the hair is 21 meters long and it has a rig with control points for posing it along the length. (Ward and others. 2010, 1.) My character is 150 cm long and the hair is knee length and no manual posing. Hairstyle and movement is controlled by base curves, attached to a scalp mesh that follows the head bone.

To understand the content of this thesis requires at least basic knowledge of making of 3D characters. Previous usage of Autodesk Maya helps to follow my steps.

I try to be straightforward with my approach of writing this thesis and creating the hair simulation. In chapter 2 I shortly explain through my software choices. In chapter 3 I introduce my start scene and the objects I already have created. In chapter 4 I make the hair simulation from generating the hair strands to rendering the hair. In chapter 5 I summarise my process.

2. Software

2.1. Autodesk Maya

Autodesk Maya, also called Maya, is a 3D computer graphics software developed by Autodesk. Maya is used for creating 3D digital content, including models, animation, visual effects, games, and simulations. (Autodesk Maya Manual 2016a.)

Maya is widely used in films, television series, and games (Wikipedia 2017b). In 2015 VentureBeat, a tech news and analysis site reported that Maya is so popular that it has been used in every visual effects Oscar winner since 1997 (VentureBeat 2015).

I use Maya as base software for my 3D studio. With Maya's tools and plugins, I can create my whole project from modeling to rendering inside Maya. I have been using Maya for all my school works and generally I used Maya for all the steps to create 3D graphics.

2.1.1. nDynamics

nDynamics is a dynamic simulation framework powered by Maya Nucleus technology. A Maya Nucleus system is composed of a series of Nucleus objects. Including nCloth, nParticle, nHair and passive collision objects as well as dynamic constraints and Nucleus solver. (Autodesk Maya Manual 2016b.)

Dynamic simulation is the way to animate deformable, soft body, objects. It's used to create effects like fire, rain, explosion, smoke, and simulate the movement of hair and clothes. It handles also the movements and interaction between static, rigid body, and soft body objects inside the Nucleus system.

I will animate the hair with Nucleus system. It will hold the physical qualities of my dynamic scene and objects, and calculate the hair movement frame by frame based on these settings. I have used nDynamics for creating hair and canvas simulations before.

2.2. XGen

XGen is an instancing framework developed at Walt Disney Animation Studios, WDAS. It lets you generate arbitrary geometry over a surface by means of maps, expressions, and guides. It's used to create geometry entities like fur, feathers, rocks, trees, flowers and of course hair. In the movie Tangled XGen was used to create and groom Rapunzel's (the main character) super long hair. (Autodesk 2011. Autodesk Maya Manual 2016c.)

XGen is developed closely with Autodesk. In 2011 Autodesk made exclusive five years license agreement with WDAS for XGen. It makes XGen accessible through Maya, which makes it easy to implement in the project. I have no previous experience with XGen and I'm excited about trying it out.

2.3. RenderMan

RenderMan is 3D rendering software developed by Pixar. RenderMan is used by Pixar to render all of their in-house 3D animated movie productions. RenderMan defines cameras, geometry, materials and lights using the RenderMan Interface Specification. This specification facilitates communication between 3D modeling and animation applications and the render engine that generates high-quality images. (Wikipedia 2017c.)

RenderMan provides a fully integrated plugin for Maya. This means, I can do my shading and render settings for RenderMan inside Maya. (RenderMan Pixar.) I have no previous experience with RenderMan, like with XGen, and I'm excited about trying it out.

3. Scene

3.1. Basic settings

To understand the process of making the hair it's relevant to go through scene-specific settings I made in Maya. The paragraphs in this chapter cover the following settings in the same order: setting a project, time slider and scene scale.

Setting a project. For Maya to be able to always find all the scene related files from a computer there needs to be project setted up. Setting a project creates a folders structure associated with the scene. Some of these folders are scenes, templates, render data and source images folders. Also, XGen and RenderMan data specific to my scene will be stored in the project folder as well. (Autodesk Maya Manual 2016d.) If the project folder is not set up, Maya might not locate some files and scene might have essential data missing. It's not generally good practice to have project files scattered around your computer. (Autodesk knowledge network 2016a. Autodesk knowledge network 2016b. Autodesk forum 2016.)

Time slider. My scene is standard 25fps. Time slider is set to go 0-300 frames, from which only the last 200 frames will be rendered. The first 100 frames are there to prepare the hair for renderable frames. Hair curves are modeled when a character is in t-pose. Which means that the hair needs to be animated from the t-pose to whatever is the character's pose in the first renderable frame. Hair movement settling time has to also be taken into count.

Scene scale. My scene is modeled to match real-world scale. It makes it easier to imagine the digital studio size and distances. Also, I'm used to seeing Maya nucleus settings effects in this scale. If my scale would be bigger or smaller effect of value changes in dynamic simulation settings would be also less effective or more effective than what I'm used to.

3.2. Scene objects

In my scene, I already have all the relevant objects that I need for starting to create the hair simulation. The paragraphs in this chapter cover the following scene objects in the same order: character, hair curves, scalp mesh, rendering camera and lights.

Character. In the middle of the scene, I have my hairless character, Muusa (Image 1). Muusa's body will take part of the dynamic solver calculations, as a nRigid object, since it's going to be colliding

with the hair. Muusa will dance during the animation. In the chapter Character animation, I'll explain the animation through.

Hair curves. I have already modeled long curves in the scene (Image 1). These long curves are the base of Muusa's hair. Curves all start from the scalp mesh and end around Muusa's knees. Later the XGen generated hair strands will imitate curves shape. Curves are also the base shape to start the movement from. They are modeled when Muusa is in t-pose. To save my computer and to keep simulation time manageable for this project, I settled for modest amount of curves and their complexity. Altogether there is 32 hair curves that each have 13 evenly distributed CVs. To compare, in movie Tangled Rapunzel's hair has 200 curves, each 21 meters long. (Ward and others. 2010, 1.) In process of making the hair curves, I made sure none of the hairs went inside Muusa's body except the root of the hair. Just like real hair does not go inside our skin along its length. If there is two colliding surfaces already touching each others really closely at the start of the simulation, it can cause the hair to get stuck or bounce. Depending on the settings in each element taking part in the dynamic simulation calculations. Which means longer settling time for the renderable frames and maybe even totally unwanted result. Same reason the curves should not touch closely each other. I didn't use a long time modeling these curves, partially because the time I wanted to use to this project in total and because I already decided to make the hair slightly curvy, by modifying the generated hair strands, to forgive some of the fast modeling job. Decision also made by having the nature of the process in mid.



Image 1: Muusa and hair curves

Scalp mesh. Inside Muusa's head is a mesh called scalp (Image 2). Scalp will be the base of generated hair strands and the hair curves will follow the scalp during dynamic simulation. The

scalp mesh is perfect shape that covers only the area Muusa needs hair. Just a tiny bit smaller so it fits inside Muusa's head. The scalp mesh is following Muusa's head joint. To achieve that, I used parent constraint.

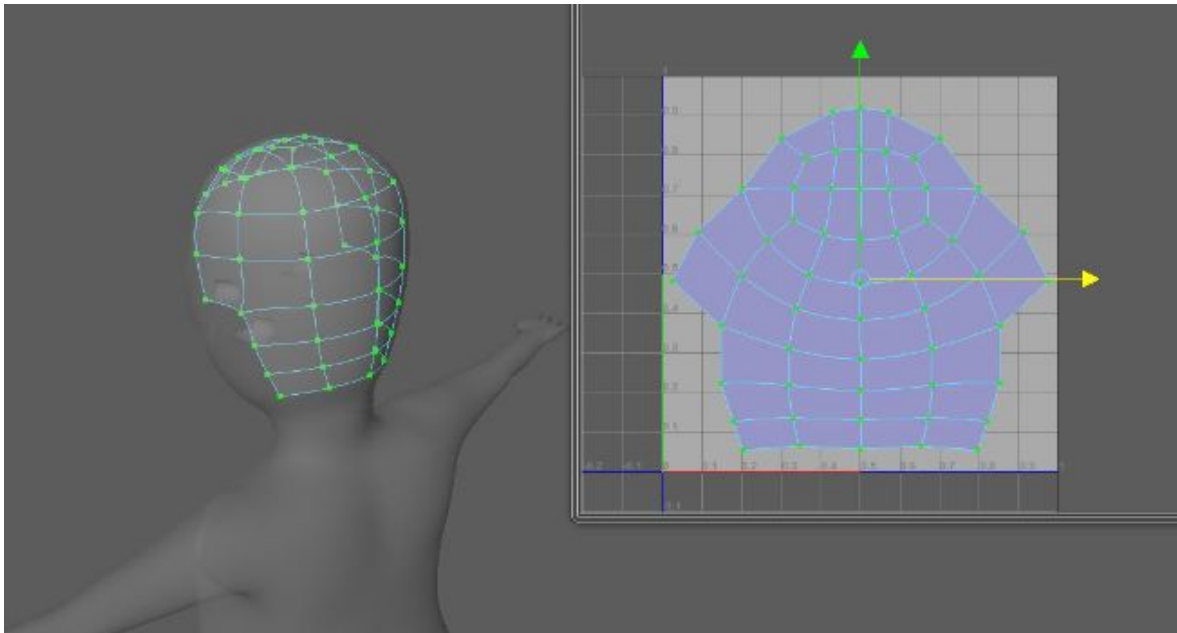


Image 2: Muusa's scalp mesh

Rendering camera. The scene will be rendered with the camera that I created, and animated to go around Muusa during the dance turn. Position and movement of the camera is simple and aimed to capture the whole hair movement and character motion together. Cameras has default settings with wide focal length.

Background. I wanted my scene to have a simple smooth background. I created a simple smoothed box mesh and I deleted the top and two walls from it. Background mesh only serves a visual purpose and it does not take part of dynamic simulation collision calculations. To make the hair to look like it's colliding with the floor, I will later use invisible colliding ground plane inside nucleus settings.

Lights. I wanted to keep my scene simple and I did settle for a simple light setup (Image 3), two main lights and one fill light. For the main lights, I created two RenderMans PxrRectLights for this scene. PxrRectLight is one-sided area light that simulates a rectangle-shaped light source. Main lights have the same settings and they are almost facing each other. Both of them are about four meters from the studio middle where Muusa is dancing. Their intensity at 17. Intensity controls the contribution of the light linearly. (Renderman Documentation 2017.) Fill light is located in front and slightly above the camera, so the fill is coming right in front of Muusa. Fill light is parented to the camera, so it continues to be in front of Muusa during the whole animation.

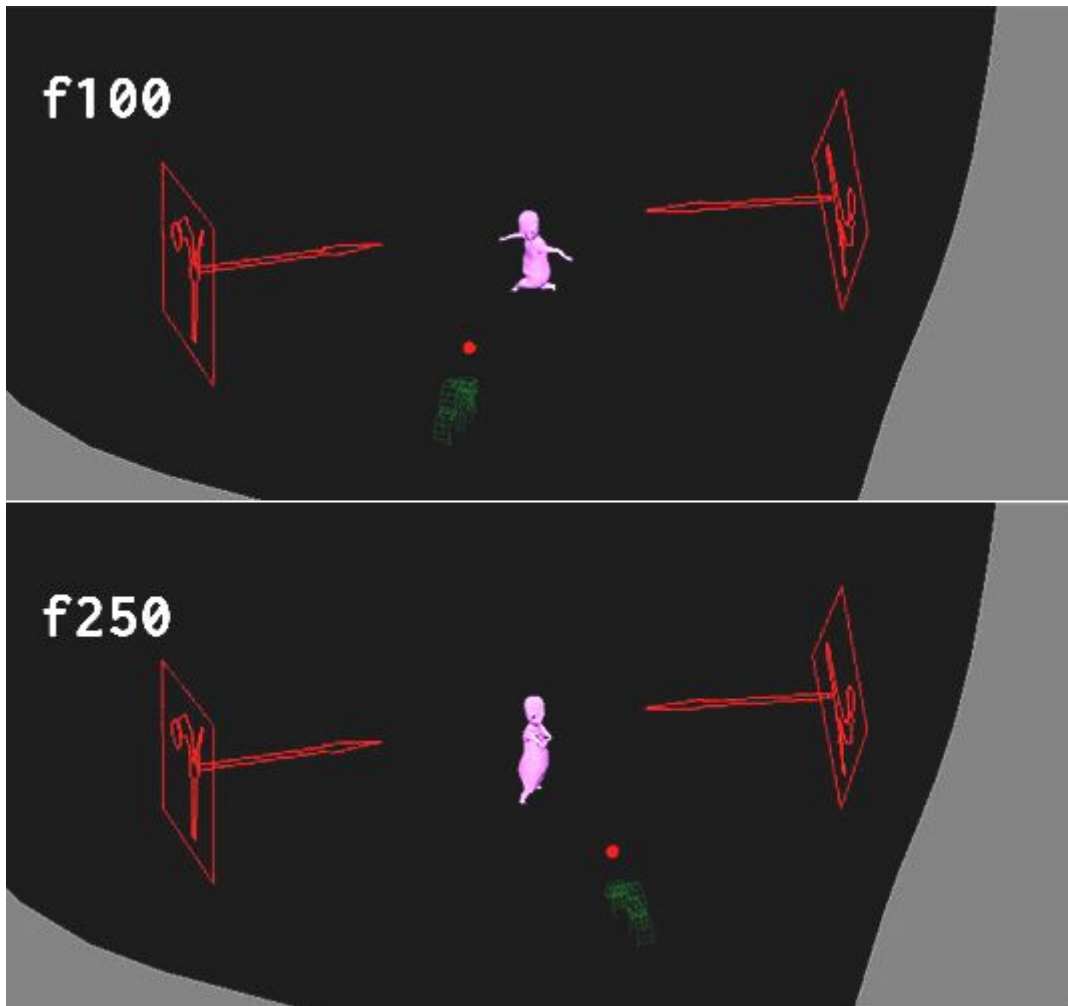


Image 3: Light and camera setup.

3.3. Character animation

I got rig and animation for Muusa from Mixamo (<http://www.mixamo.com/>). Mixamo develops and sells web-based services for 3D character animation. The animation is a breakdance turn that starts and ends in a still pose. I wanted to have a movement that starts still, changes to have fast motion and stops. So that the hair has to start still, follow nicely the movement and settle at the end. I wanted to work on a difficult motion, to see how much control I can achieve. I already learned, from my previous hair simulation experience, that it is hard to maintain beautiful swing and flow in the hair movement and still have realistic settling time when the movement finishes.

I needed to make a few changes to the character animation to make it fit the hair simulation purposes in my scene. I changed the dance animation to start later in the timeline, to have time to animate Muusa from the t-pose, where the hair curves are modeled, to animation the start pose, and have some frames before renderable frames, to give the hair time to settle. I animated Muusa to go from t-pose to breakdance animation start up pose during the first 25 frames. After that I

made Muusa keep the same pose for 75 frames, to let the hair movement settle. At the frame 100 renderable frames start and the hair should be ready for render. I also animated Muusa's left arm to have a more straight line during the dance turn between frames 165-190. So that the arm can swipe all the hair with it during the turn. Image 4 shows the end result of the break dance animation with selected frames.

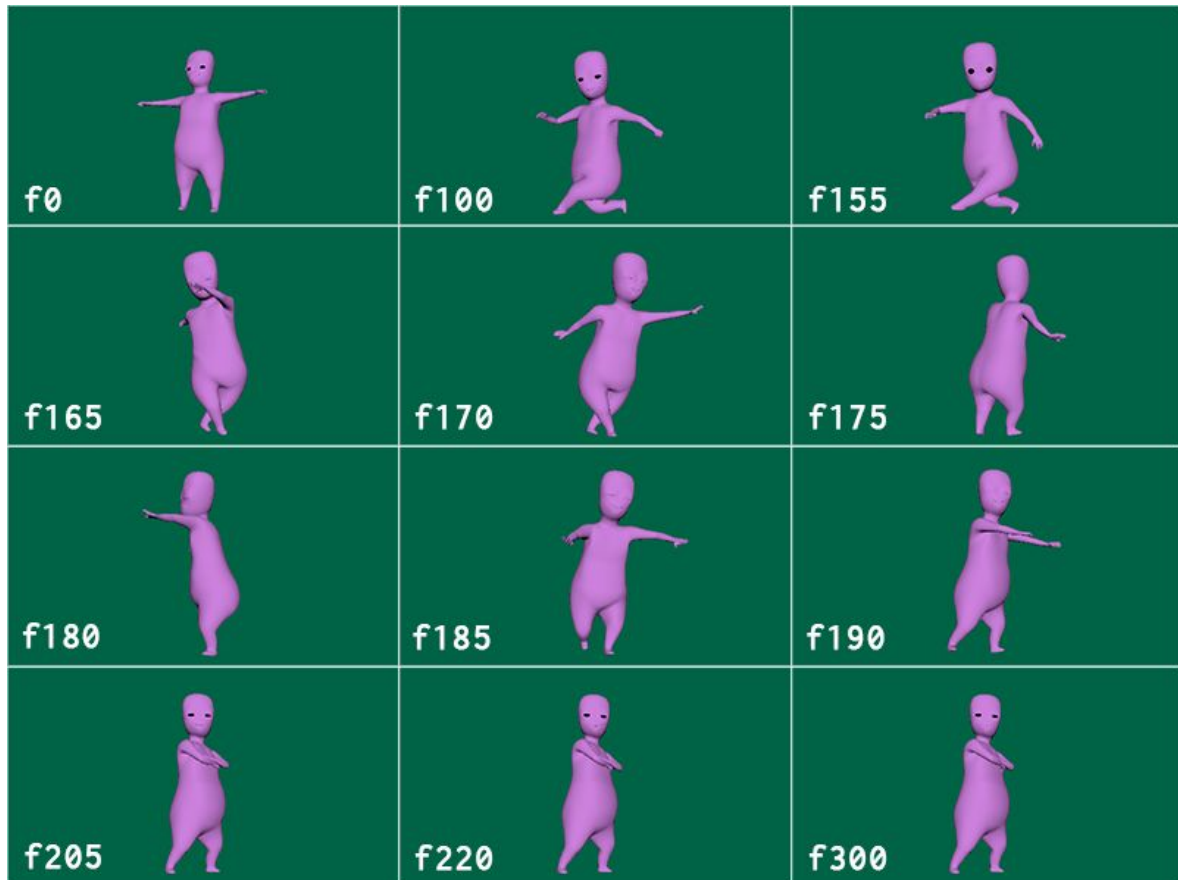


Image 4: Selected frames of the animation

4. Making the hair simulation

4.1. Making XGen hair guides

Now that I explained my scene through it's time to add XGen to the scene. I'll make XGen hair guides from the scene's hair curves. The guides will be geometry that all hair strands follow and imitate as in their basic form. Before I can create the guides I need to invite XGen to the scene by creating XGen description. XGen description will hold all the XGen hair data.

4.1.1. XGen Description

XGen organizes and stores all settings for positioning, generating and rendering instanced primitives, hair strands, in XGen Descriptions. Descriptions are contained and organized in Collections. This is XGen's way to organize data. It means Muusa's hair settings will be stored as description under Muusa's own Collection. If I would make different kind of hair for Muusa, example armpit hair, I would create new Description under Muusa's Collection. (Autodesk Maya Manual 2016e.)

To create XGen Description to my scene I need to attach it to a polygon surface, which will be the surface for hair primitives to generate from. In my case, XGen hair has to be associated to the scenes scalp mesh. While scalp mesh selected I created Description by going XGen > Create Description.

Before XGen actually makes the description Create XGen Description-settings window pops up. In here I need to name the description and the collection, and select some basic settings for storing and editing the XGen data. These settings will affect the hair strands look and control. First, in Create XGen Description-settings, I select what kind of primitives are made by the description. I select splines. They are perfect for Muusa's long hair. Spline primitives are like curves made up of two or more segments and their width can be controlled along the length (Autodesk knowledge network 2016f). This way I can use the hair curves in the scene to be transformed into the guides. Next, I need to decide how primitives will be generated. I select primitives to be generated randomly across the surface. Again this is a good setting for using already existing curves with XGen description. Last thing I need to select is how I will control the primitives. I select to control primitives by placing and shaping guides. This will make hair strands obey the placing and the shape of the guides (Autodesk Maya Manual 2016f).

I press Create. Nothing visible happens in my scene. It's because I don't yet have any guides attached in my hair description. There is no example of hair for hair strands to start to imitate.

4.1.2. Creating XGen guides from curves

XGen guides are geometry that place, shape, and orient primitives generated on polygon meshes. Guides determine where primitives will be generated and how do they look. XGen has tools to modify, delete and add guides on the face of a polygon surface. There can be any number of guides in any area of assigned polygon surface. (Autodesk Maya Manual 2016c. Autodesk Maya Manual 2016g.)

To get guides to my XGen description I attach my already existing hair curves from the scene to be guides. In XGen window I go to Utilities tab. XGen Utilities have tools to shape and modify XGen guides. I use a tool, for making curves to guides, called Curves to Guides. I leave the tools settings as default. I select all my hair curves in the scene and in the tools menu I click Add Guides-button.

Now the guides are attached to the description. To see the generated hair strands I update the 3D scene window by pressing preview icon in XGen editor. Now I can see the hair strands generated around the guides (Image 5). At the moment, it seems like Muusa is bald at to top of the head. It's because the default hair strands have only a few segments in their geometry, that's why they can't imitate guides perfectly.

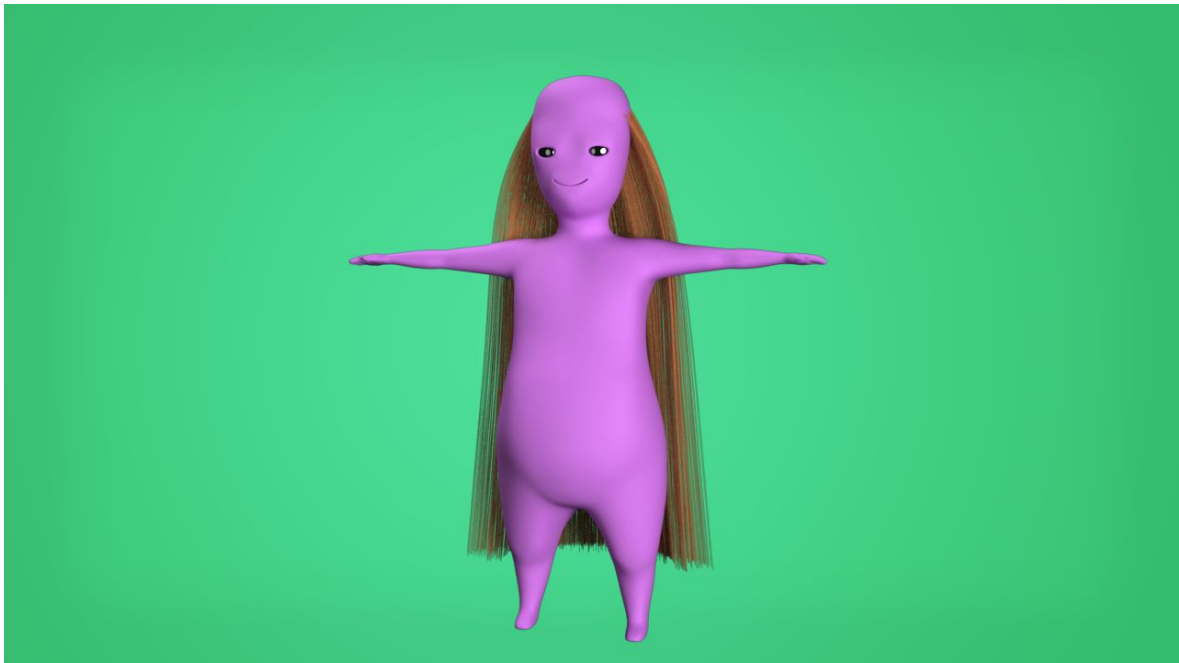


Image 5: Muusa and primitive presets.

4.2. Shaping the hair strands

Now that I generated the hair strands it's time to define how they shape and behave around the guides. XGen provides different ways to control the location, behavior and look of hair strands (Autodesk knowledge network 2016h).

4.2.1. General settings

To be able to shape and give details to the hair strands, I first do the settings for their general geometry settings. This will add the needed detail to the strands geometry. After that, I can start to add more shape details to them with modifiers.

To edit the hair strands I go to XGen > Primitives. Primitives tab has categorized subsections for different primitive hair strand settings. Next paragraphs covers the settings I will make in the subsections called generator attributes and primitive attributes in the same order.

Generator Attributes affect how hair strands are generated around the scalp. Some of these settings I made already while creating the XGen description in the previous chapter. Others control the amount and visibility of the strands. In here I only change Density value from 1 to 10. Density controls the number of hair strands generated from the scalp. This made Muusa's hair denser. (Autodesk knowledge network 2016j.)

Primitive Attributes effect to the hair strands complexity and width. First I change Modifier CV Count value to 40. This sets the number of CVs to 40 on each spline. This makes the hair strands imitate the guides shape and to have enough geometry so that they can be shaped with modifiers. Second, and last thing I change in Primitive Attributes, is the Width Ramp. With Width Ramp I set width along the length of hair strands from root to tip. I want the hair strands to be thinner towards the tip. I alter Width Ramp so that after halfway of the hair strands they start to get thinner and at the tip they are half thinner than at the root. I change the Interpolation value to be smooth along the width change. (Autodesk knowledge network 2016k.)

Muusa isn't bald anymore. Instead the hair primitives are nicely imitating the guides and also have altering width along their length (Image 6).

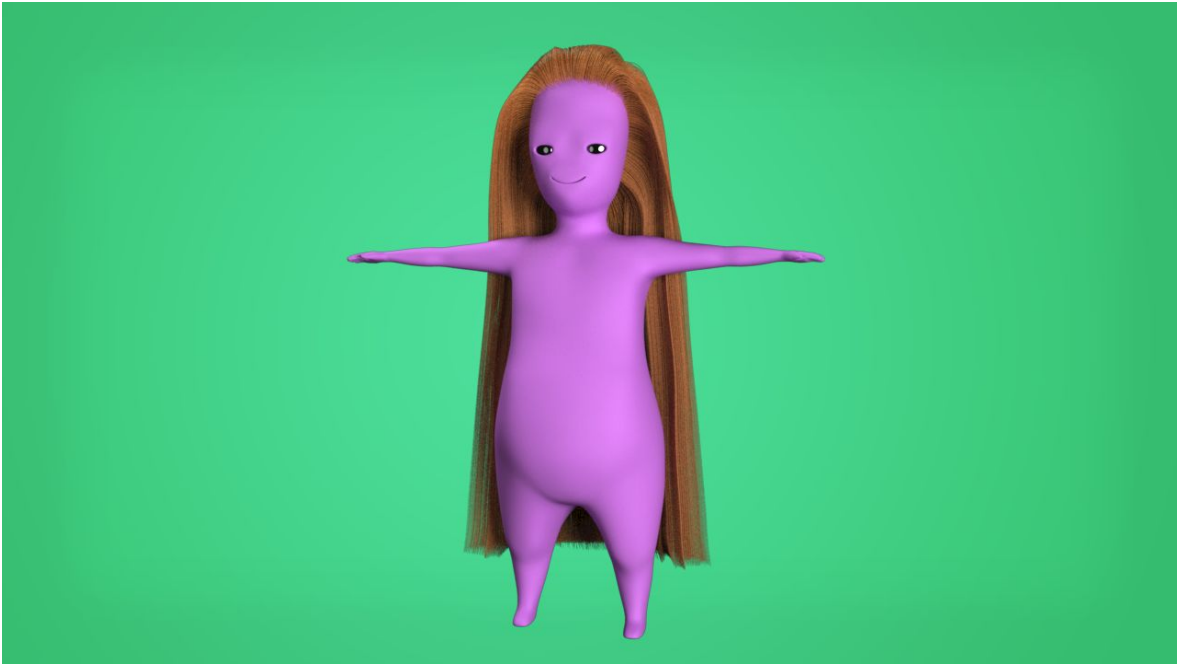


Image 6: Hair with general primitive, hair strand, settings done.

4.2.2. Modifiers

After getting the hair strands amount and geometry complexity right it's time to modify their appearance and behavior around the guides. Look wise I want the hair to have mild waves and have little bit natural mixing of strands. Behavioral wise I want to set the hair strands to avoid getting inside Muusa's body.

To make these changes I open XGen > Modifiers. Modifiers tab has a selection of modifiers that help to style hair strands and define their behavior. Next paragraphs cover the following modifiers I select to style the hair strands in the same order: coil, noise, collision and clump.

Coil. For Muusa to have wavy hair, I add Coil modifier. Coil modifier makes hair strands curl around the guides. I change Coil modifier Count value to 7, this sets the number of coils along the length of the hair strand to be 7. (Autodesk knowledge network 2016m.) Now the hair has nice mild waves (Image 7).

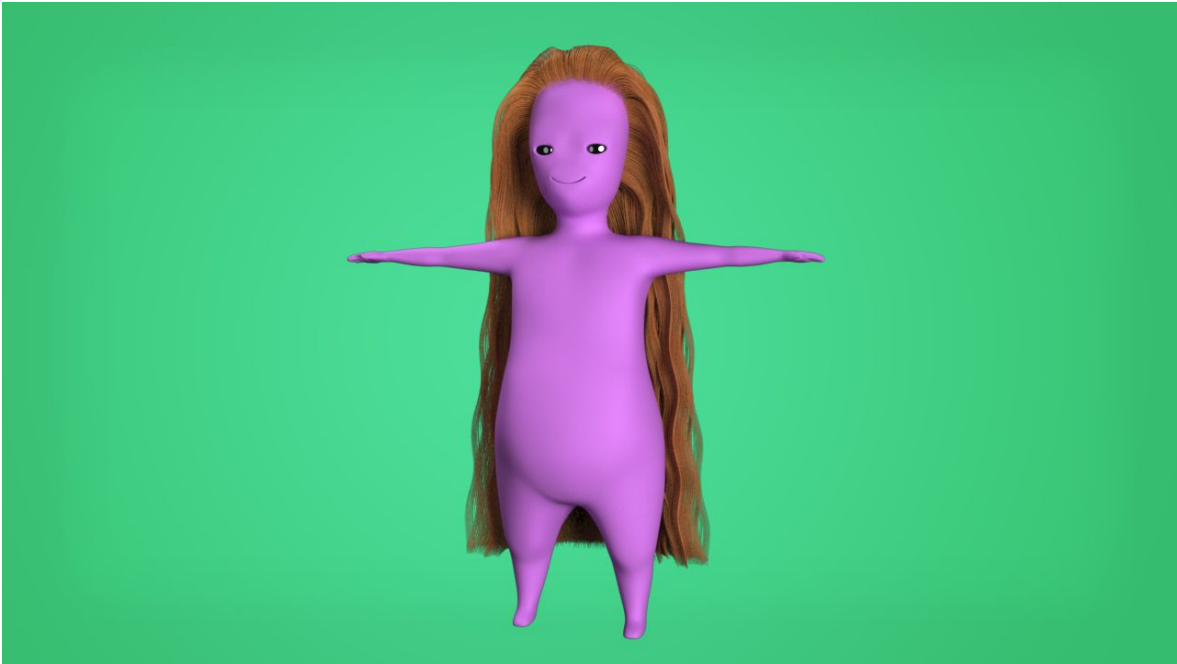


Image 7: Coil modifier added to XGen description

Noise. To make Muusa's hair to have natural mixing between the strands, I add Noise modifier. Noise modifier adds three-dimensional noise to hair strands, to break the straightness of the strand. I put Frequency value to 4, to affect how often change is applied to the hair strand. Then I set Magnitude value to 5, to affect how far can hair strand displacement go. In Magnitude Scale ramp I can affect how much Noise modifier effects along the hair strand length. I change root value from 0 to 0.5, to make the hair strands to be affected by the modifier all the way. (Autodesk knowledge network 2016n.) The effect is mild, but important for breaking little bit otherwise perfectly aligned hair strands (Image 8).



Image 8: Hair without (left) and with (right) noise modifier.

Collision. I want hair strands to avoid going under Muusa's body, I add Collision modifier. Collision modifier can detect and resolve collisions between hair strands and assigned collision object. In my case, the collision object is Muusa's body. This means that during the simulation, when the hair strands collide with Muusa's body, the modifier pushes the hair strands away from Muusa's body based on the settings defined in the modifier. I set Resolve Type value to be Flexible, this pushes hair strand inside Muusa's body onto the closest points on its surface. This way the hair should stay on the character's skin and not bounce when collision is detected. Next, I assign Mesh File. Mesh file needs to point out to a file containing collision object and the animation. To create alembic cache I select Muusa, then I go to Cache > Alembic Cache > Export Selection to Alembic > . I create the cache for frames 0-310 and I save it to my project files. For hair animation purposes it is better to make all animation caches influencing to hair to start when the hair positioning start. Then all the calculations for hair behavior start at the same time. If I would start the alembic from frame 100, where the rendering frame starts, there might be some jumping in hair primitives, because there would be surprising new collision taking place in the middle of hair settling. In the modifier I point Mesh File to be the alembic file I just created. (Autodesk knowledge network 2016. XGen Collision modifier options)

Clump. To control witch hair strands follow which guides and how closely, I add Clump modifier. This also helps hair strands not to get stuck under Muusa's body. I change the Clump Scale ramp tip value to 0.25 from 0, to make the hair strands to go only slightly more closely to the guide towards the end of the tip. Next I want to create clumping map to tell the hair strands which guide to follow. By clicking Setup Maps button I open Generate Clumping Maps window. To get the

generated clump map result based on the guides I click Guide button. Now hair strands follow the closest of their hair guides. To see which primitives are assigned to which guides I press Colour Preview checkbox on to displays the colors of the clump maps (Image 9). (Autodesk knowledge network 2016p.)



Image 9: Clumping maps defining witch hair strands follow witch guides.

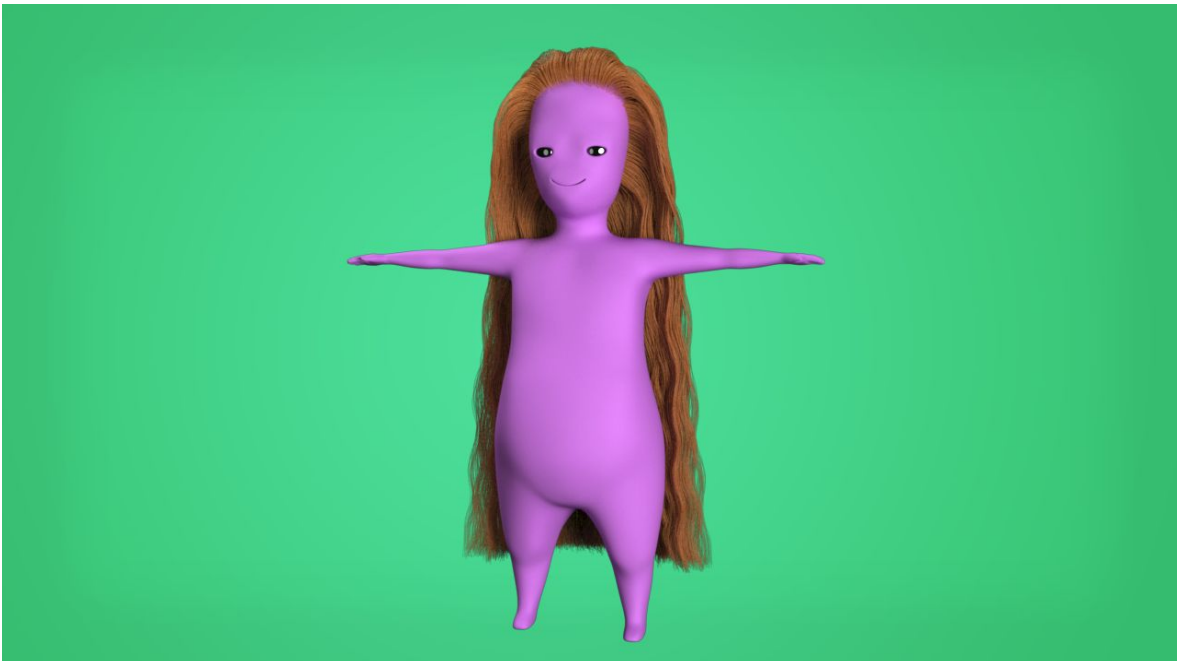


Image 10: All modifiers added

4.3. Hair output settings

Hair has been shaped to my liking (Image 10) and now it's time to change rendering settings in XGen and shade the hair strands blue with RenderMan's hair shader, PxrMarschnerHair.

To change the output settings for the hair, I go XGen > Preview/Output. Preview/Output tab has settings for how the hair looks while viewing in the 3D scene and when rendered. Next three paragraphs cover the following settings I change in Preview/Output tab subsection Output Settings in the same order: renderer, primitive bound and RenderMan shading group. Last, fourth, paragraph is about RenderMan's hair shader and about the changes I make in it.

Renderer. I noticed that by the default renderer has set to MentalRay. I change it to RenderMan. Since that's the renderer I want to use.

Primitive Bound. Primitive Bound sets the boundaries for XGen elements when rendered. Setting this right will prevent hair strands to clip when rendering. I let Maya automatically calculate the primitive bound for me, by clicking Auto Set button next to Primitive Bound, and then I round up the number. (Autodesk knowledge network 2016r.) Primitive Bound value is now 129.

Renderman Shading Group. To change hair shader I go to RenderMan Settings subsection inside output settings. I select Create PxrMarschnerHair from a drop-down menu next to Shading Group attribute.

PxrMarschnerHair shader is designed to render realistic hair, fur and fibers. (RenderMan Documentation b.) The default shading settings give a dark brown hair for Muusa (Image 11). I want the hair to be lighter and blue color. I change Diffuse Gain value to 1 from 0 and Diffuse Color to light blue. To make the highlights visible in lighter hair I change Glint Gain value to 1 from 0. Finally I make the Primary, Secondary and Transmit Specular Colors to fit for the blue hair. Muusa's hair is now a beautiful light blue color (Image 11).

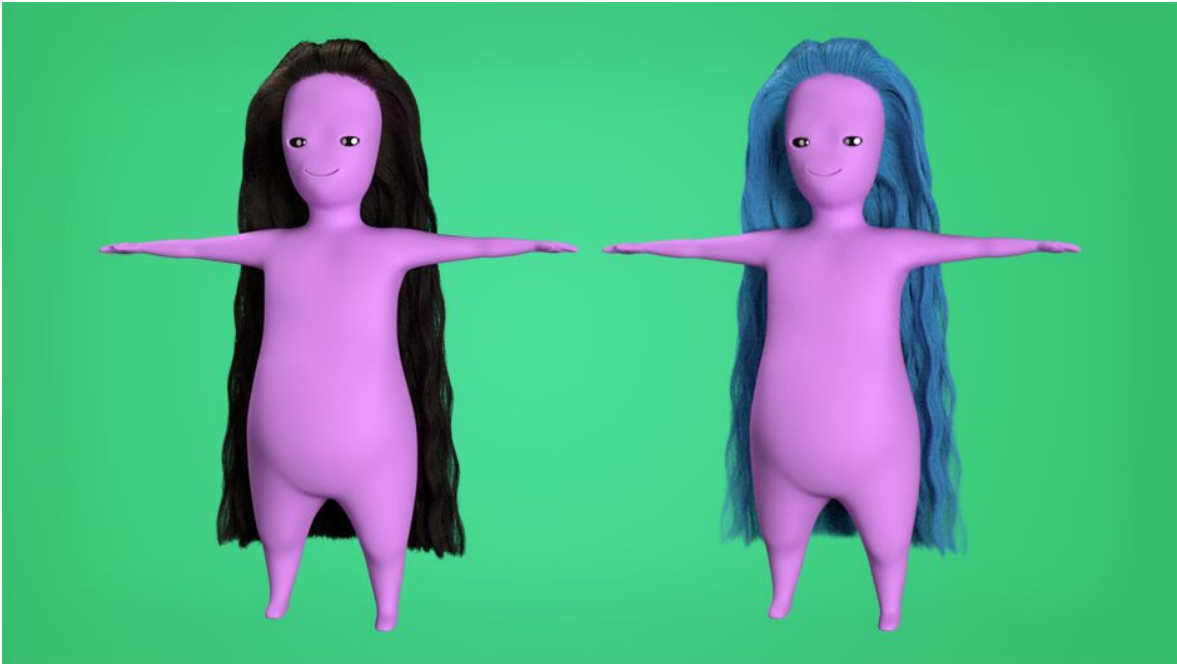


Image 11: Muusa with PxrMarschnerHair shader presets (left) and my edits (right)

4.4. Animating hair


Now that the hair looks good it's time to make it move. Next, I'll go through the steps of animating the hair with Nucleus dynamic simulation system. I start by explaining tools for observing simulated hair results, then I add nucleus to the scene and go through setting up all the nucleus elements, and their settings, to be ready for the render.


4.4.1. Viewing hair simulation during the process

In Maya, there are different ways to view hair movement during the simulation process. Next paragraphs will cover following tools and their use when viewing simulation in the same order: time slider, playblast and nCache.

Time Slider controls the playback range, keys and breakdowns within the playback range (Autodesk Maya Manual 2016h). I set time slider to play animation frame by frame. Now animation playback speed depends on how long it takes the computer to calculate each frame. This is good while creating a dynamic simulation. With dynamic simulations Maya has to have time to calculate dynamic objects movement on every frame. Otherwise the end result of the simulation is ruined, since Maya does not have time to calculate simulation movement between

frames. To change Playback Speed to Play every frame free, I right click time slider and select Playback Speed > Play every frame free.

Playblast is a workspace render of any currently selected camera window. Playblast takes the time to render as it takes the computer to calculate every frame. After calculation I can find my playblasts from my project folders. I create playblasts in multiple points of my simulation process, to have good information of real time movement of the hair. Without using playblast it is hard to analyse the hair realtime movement. To create playblast, I first select my render camera view, then I right click time slider and select Playblast . In Playblast Options I make sure the format is video, in my case avi, and I change name suited for the playblast. (Autodesk knowledge network 2016t.)

nCache saves the movement information of wanted nucleus object into a file, in my case the hair curves. This information can be called to define the hair movement. Instead letting the computer to calculate the movement on each frame. When the object movement is coming from a file it is possible to browse time slider (Autodesk Maya Manual 2016i) I create nCache file of the hair movement when I want to observe it from all the angles while browsing the time slider and when I'm happy with the movement at the end. To create the nCache file for the hair curves I select all the curves affected by the dynamic simulation in Outliner window, then I select nCache > Create New Cache > nObject . In Create nCache Options window I let Maya decide where to store and how to name the nCache. I also used the default Mayas 64-bit cache file format .mcx.

4.4.2. Adding Nucleus system to the scene

Next, I go through getting Nucleus system in my scene trough XGen window. Maya will create another set of hair curves for the simulation. These dynamic curves will be simulated under Nucleus system and XGen will use their movement data to animate hair strands in preview.

To get Nucleus and dynamic hair curves to my scene I go to XGen window > Primitives > Guide Animation. I select Use Animation checkbox and click Create Hair System. Make Curves Dynamic Options window pops up and Maya automatically selects scalp mesh and hair guides from the scene. I leave preset settings and click Make Curves Dynamic. Maya creates set of dynamic curves, identical to my hair guides, attached to scalp mesh. Maya also creates nucleus and hairSystem nodes into my scene.

Currently XGen is still using old non dynamic Guides to position spline primitives. To make spline primitives follow dynamic curves, I select all the dynamic curves in the outliner and click Attach

Hair System in XGen window > Primitives > Guide Animation. In outliner I hide XGen guides that now only effect for the hair groom.

4.4.3. Setting up nRigid object

Passive collider under nucleus system is called nRigid object. To make dynamic curves collide with Muusa's body, I need Muusa's body to be part of nucleus system as nRigid object. To do this I select Muusa's body mesh and go nCloth > Create Passive Collider. It will be assigned under my only scene nucleus node by default. (Autodesk knowledge network 2016u.)

To affect the nRigid object collision settings I go to nRigidShape > Collision. First I change Collision Thickness value to 7 from 7.476. When creating nRigid object Maya automatically estimates good average value for the collision thickness. In my case the estimated thickness size is good, but I just want the value to be a sharp number. I also change Friction value to be 0 from 0.1. I don't want Muusa's body to have any resistance to the hair movement. (Autodesk knowledge network 2016u.)

I want to make nRigid object detect if the hair gets stuck under collision mesh, and what to do with it during the simulation. I go to nRigidShape > Quality Settings. I check Trapped Check checkbox. So that Maya will check for trapped hair while calculating the movement. Then I change Push Out Radius to 0. I don't want nRigid push out violently dynamic curves that are stuck under the mesh. This also makes dynamic curve roots to not jump out of the head. (Autodesk knowledge network 2016u.)

To see my starting point I take the first playblast. Hair has never ending, wild, floating movement. As shown in the next Image 12. To start to control this wildness, I'll do changes in the scenes physical settings in nucleus node.

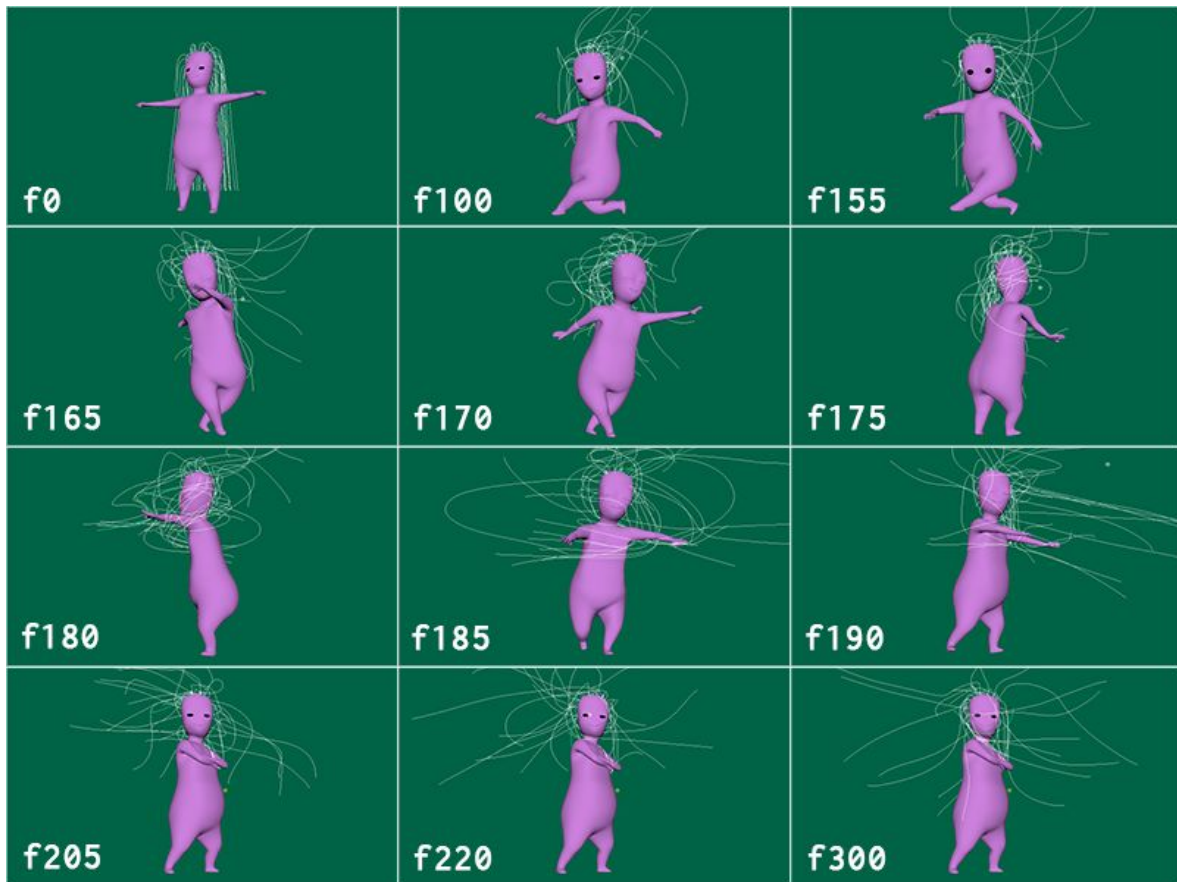


Image 12: Selected frames from playblast taken with only nRigid settings done from Nucleus objects.

4.4.4. Nucleus settings

Nucleus node has settings for the environment physical qualities as well as simulation quality, that have effect in objects under the nucleus system. (Autodesk knowledge network 2016v.) Next three paragraphs cover the settings I change in following sections in nucleus node in the same order: Ground Plane, Solver Attributes and Scale Attributes.

Ground Plane is an invisible colliding plane. I turn on Use Plane checkbox. By default the colliding plane is in the center of the coordinates. In a perfect place to simulate the floor collision for my simulation.

Solver Attributes affect to the quality and the time it takes to calculate the simulation. I change values in Substeps and Max Collision Iterations. Both of them affect how many times movement is being evaluated per frame. Substeps attribute affects the number of times solver calculates movement per frame. I change the value from 3 to 30. I need lot of substeps for nucleus to be able to calculate hair movement well when there is quick movement. Especially when Muusa does the dance turn. Max Collision Iterations specifies the maximum number of collision iterations per simulation step. I change Max Collision Iteration value from 4 to 50. The Higher the number the

more accurate the end result will be. It also takes longer to calculate. In process of tweaking these values, I noticed that super high solver values also gave me slower movement of the hair. (Autodesk knowledge network 2016v.)

Space scale determines the relative space scale applied to the scenes elements under nucleus. Gravity interprets Maya's units as meters. I have my Maya units as centimeters. This means gravity treats my scene 1 centimeter as 1 meter, when Space Scale is still on its default value 1. Which means that dynamic curves are behaving like they were huge, like massive floating strands. I change the value to 0.01 since I want my physical space mach real life scale. (Autodesk knowledge network 2016v.)

After making changes in nucleus node I take another playblast (Image 13). The hair doesn't float around anymore. Instead it flaps around with seemingly more weight on it. The motion still feels like it's never going to settle. Also, there is quite noticeable stretching happening in the hair curves, because the curves have now more weight in them after scaling the physical space.

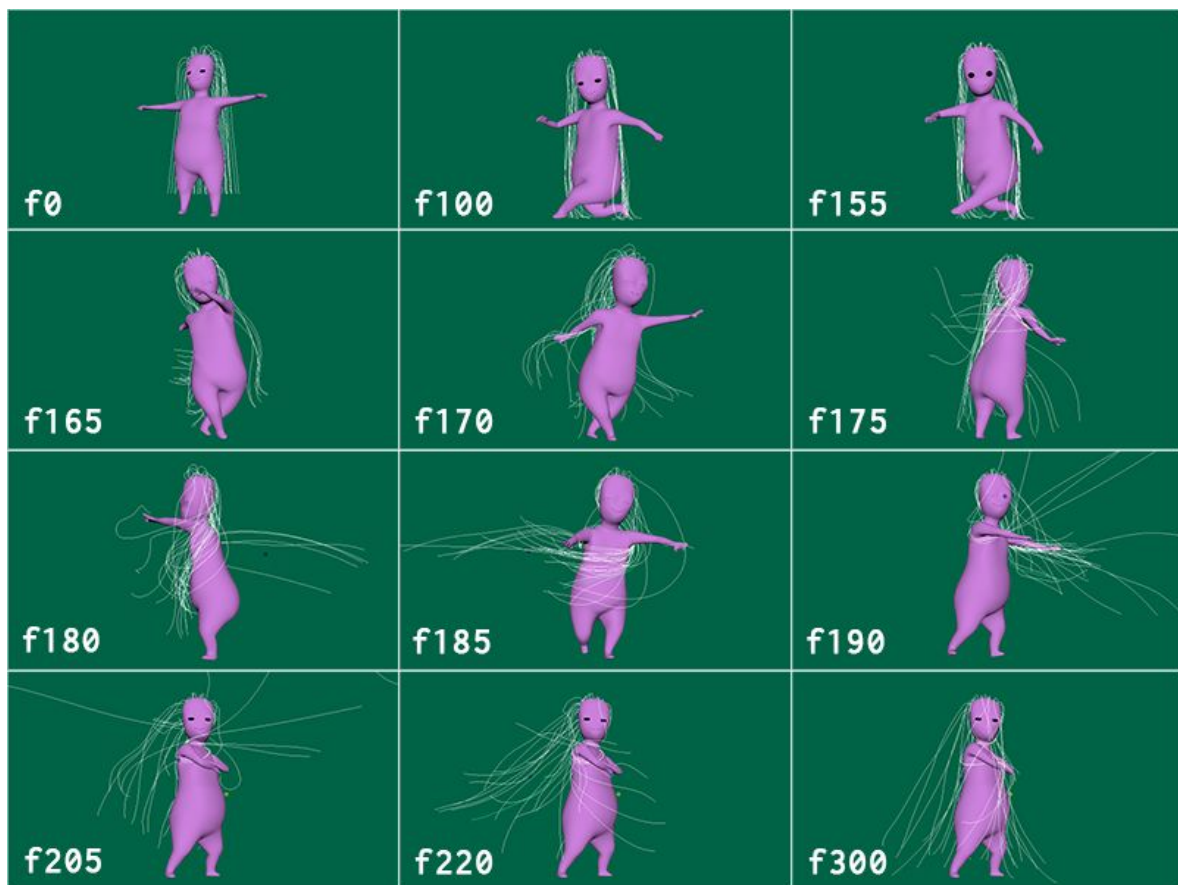


Image 13: Selected frames from playblast taken after changing nucleus and nRigid settings.

4.4.5. HairSystem settings

HairSystem settings affect on dynamic curves physical qualities in Nucleus system. I want Muusa's hair movement to be close to realistic. Hair should stay still while Muusa is still, have nice controlled motion while Muusa makes a dance twirl and settle down after a small swing. Next four paragraphs cover the settings I change in following sections in HairSystemShape node in the same order: Collision, Dynamic Properties, Stiffness Scale and Forces.

Collision settings affects how the dynamic curves collisions are handled during the simulation. I turn on Self Collide. This makes the dynamic curves collide with each other. Next, I change Max Self Collide Iterations value from 1 to 10. This gives me less jittery solve. Then I change Self Collide Width Scale attribute value from 1 to 320. This makes dynamic curves collision surface to be wider, so that they keep good distance to each others and the hair keeps the wanted form better. Last thing I change is Friction value from 0.5 to 0. I don't want the hair curves to stick to each others or restrain each others movement while touching each other.

Dynamic Properties settings affect what kind of dynamic properties are affecting the dynamic curves during the movement calculations. First, I change Stretch Resistance value from 10 to 100. This makes dynamic curves strongly resists stretching even when under tension, like in high speed and quick movement. I don't want any clearly detectable stretching happening for the hair. Real hair would not stretch either. Then I change Compression Resistance value from 10 to 100. To make the dynamic curves resists compression along the segments. Real hair does not compress visibly. Last thing I change is Extra Bend Links value from 0 to 4. This adds bend links between the vertices of the dynamic curves that are not close to each others. This makes the dynamic curves movement to be more uniformed and the whole hair to keep its form better. Too big a number created indecisive movement in dynamic curves and also made it look too much like a stiff blob.

Stiffness Scale settings affect the overall stiffness from root to tip of the hair. It multiplies the effect of Bend- and Twist Resistance. (Autodesk knowledge network 2016w.) I change Stiffness Scale graph attribute from 1 to 0 along the whole length of the hair. I noticed that different stiffness along the curve makes the root of the dynamic curves stuck stupidly after Muusa turns. I don't need the stiffness to vary along the length of the dynamic curves I decide to take Stiffness Scale off from use totally.

Forces settings affects to the dynamic curve's internal forces by how heavy the object is, and how much movement damping and dragging there is. First I change Mass attribute value from 1 to 0.1. This sets the simulated mass of the dynamic curve vertices. I want the hair to be lighter, so it

would not slap around like a heavy rope. Lighter than 0.1 made the hair slowly float to its place like a thin curtain, that was too light. Next, I change Drag attribute value from 0.05 to 0.045. Drag makes friction with the air. It helps to slow down and stabilise the movement, but takes away the liveliness. Taking a tiny bit of the drag away made the hair just a bit more alive and playful and it helped dynamic curves to settle more punctually at the end of Muusa's turn. Then I change Tangential Drag attribute value from 0.1 to 0. Tangential Drag determines the amount of drag along the dynamic curve direction. I want the dynamic curves to be able to follow their own direction without any drag. This helped make nicer flow in the dynamic curves when Muusa makes the twirl. Second last setting I change is Motion Drag value from 0 to 1. This damps the movement of the dynamic curves relative to the movement of their root. Result dampens small excess movement in the tip of the dynamic curves. Last setting I change is Damp value from 0 to 0.045. This dampens the relative shape change of the dynamic curves individually affecting how they bend and stretch. Changing this attribute also helps to settle the hair nicer after motion. (Autodesk knowledge network 2016w.)

Now the hair movement is more controlled and realistic (Image 14). The hair does not stretch and get messily all over the place anymore. I had to compromise liveliness and some cartoony bendy swinging, that I wanted to have, to achieve the control and reasonable settling time.



Image 14: Final animation result with dynamic curves

4.5. Rendering

4.5.1. Alembic file of the dynamic curves for batch render

For Maya to be able to batch render the hair it needs a written file of its movement. I need to make an alembic file of the dynamic curves and make XGen guides to use that as the source of their movement. (Autodesk Maya Manual 2016j.)

To create alembic cache I select the dynamic curves, then I go to Cache > Alembic Cache > Export Selection to Alembic > . I create the cache for frames 0-300 and I save it to my project files. To use the alembic file I go to XGen window > Primitives > Guide Animation, and I change the Cache File Name to be the alembic. I take Live Mode off from use, because the movement is not driven by Nucleus system anymore.

4.5.2. Render layers

I render three render layers. One for the hair, one for Muusa without hair and one for the background. All of the layers have same scene objects, but with different visibility settings. Invisible objects will still cast shadows, bounce light, show in reflections and effect to the hair visibility to the camera. This way I create smooth and nice alpha for hair and Muusa and it gives good control in postprocessing.

I hide HairSystem node from Outliner. I noticed that when visible it did create extra black curves in the render. HairSystem has its own hair strand generator and the extra black curves were made to my scene by it.

In Hair layer, the hair is the only visible object. Muusa and background need to be invisible, but still cast shadows and reflections, and mask the hair. For this purpose I will add Holdout attribute to Muusa and background object's shape nodes. First, I select Muusa shape node and in attribute editor menu I select Attributes > Renderman > Manage Attributes. Add/Remove Attributes window pops up. I add Holdout attribute. In the shape node, I make sure Holdout checkbox is checked. I repeat setting up the Holdout attribute for the background.

In other render layers, Muusa without hair and background, the hair should not be visible. Hair should still cast shadow and reflections. To do this I need to add Renderman Camera Visibility attribute to XGen description shape node. I select XGen description shape node, and in attribute editor menu I select Attributes > Renderman > Manage Attributes. Add/Remove Attributes

window pops up. I add Camera Visibility attribute. In the node I uncheck the checkbox, to make the hair invisible to the camera.

4.5.3. Render settings

It's time to get the animation out from Maya. Before that I want to change some of the rendering settings. In the next paragraphs I go through changes I make in render setting tabs in the hair render layer in the same order: Common Settings, Sampling Settings and Features.

Common settings. In File Output section I change Image Format to be OpenEXR. I want to use common HDR image format for this project. I also change Frame/animation extension to be name_#.ext. Next, I move in Frame range section and I set the Start frame to be 100 and End frame to be 300. Then in Renderable Cameras section I select renderable camera to be the camera I created and animated for the scene. In Image Size section I change the image size to be HD 720 from the presets.

Sampling settings. I change Min Samples value from 0 to 64. With this I made sure all the pixels would be calculated at least 64 times. I was happy how much noise I got away by raising this number. Then I change Max Samples value from 128 to 1024. So some of the pixels would be calculated 1024 times before render finishes. This gives me nice almost noiseless end result. To get rid of even more noise in dark areas I change Dark Falloff from 0.1 to 0.02. Next, I go to Integrator section. Renderman has different kind of integrators. Integrators have different ways of analyzing the light in the scene. The default one, and the one I'm using, is integrator called Path Tracer. It is one of the final-quality integrators in Renderman. Only thing I change in integrator settings is Max Path Length value from 10 to 4. Because I only have one character and simple background in my scene I don't really need long light paths calculated for good render. Last subtab in Sampling settings I do changes in is Default Ray Depths. Here I can affect to Max Specular Depth and Max Diffuse Depth. Values take effects in the indirect specular and diffuse quality. I change Max Specular Depth from 4 to 2. Mainly to reduce render time. I did not see any noticeable result in my scene by dropping this number to 2. Mainly because the scene is really simple and does not need many secondary bounces. (RenderMan Wiki 2017b. RenderMan Wiki 2017c.)

Features. In Features tab I can add special features to render result. Here in Motion Blur section, I add motion blur and camera blur for my render.

4.5.4. Render passes

Renderman calls render passes involved with light LPEs, Light Path Expressions. LPEs specify what light transport paths to render. I will refer them as passes. For hair layer, I render five passes. Two for diffuse and two for specular light. One final beauty to be alpha and reference for compositing.

To create passes for hair layer I go to Render settings > Passes tab. I select all passes I need to build final beauty image of the hair. Color directDiffuse pass for straight light diffuse, color indirectDiffuse pass for bounced light diffuse, color directSpecular pass for straight light specular, color indirectSpecular pass for bounced light specular (Image 15). (Renderman Wiki 2017g.)

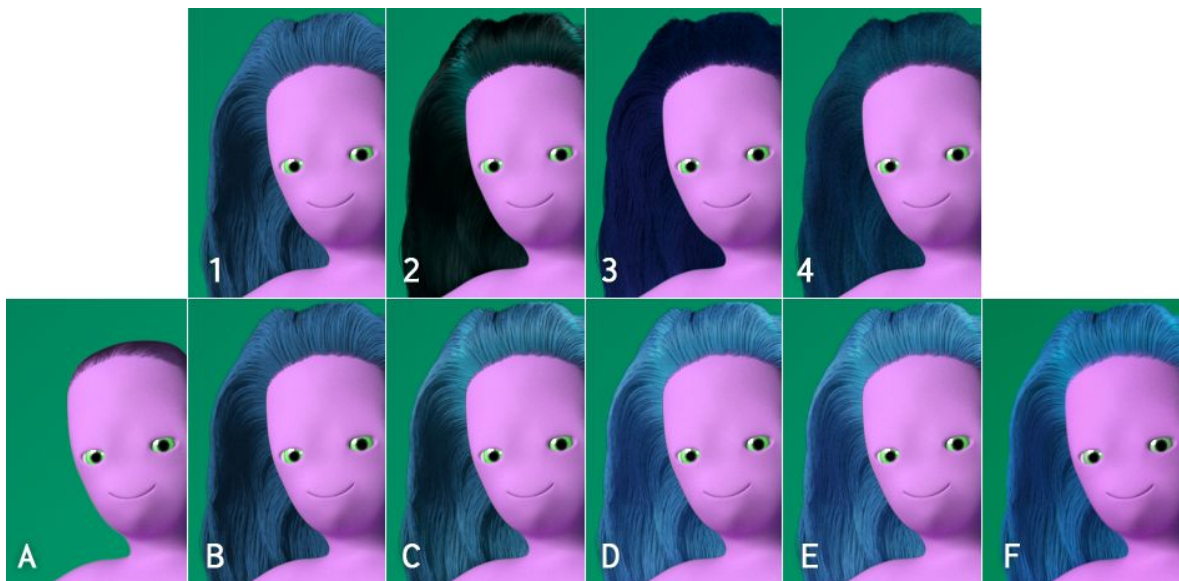


Image 15: First row, rendered hair passes : 1) direct diffuse, 2) direct specular, 3), indirect diffuse 4) indirect specular. Second row, combined images : A) Character, background and hair shadow, B) direct diffuse, C) direct diffuse + direct specular, D) direct diffuse + direct specular + indirect diffuse, E) direct diffuse + direct specular + indirect diffuse + indirect specular, F) All layers and passes + final comp touches.

4.5.5. Batch render and final result

To start to render .exr image sequence of my scene I go to Renderman > Batch Render. After render I did combine the layers and did little color corrections. In Image 16 you can see the selected frames of the final animation. The video of the the final animation is published online on my Vimeo account. Link to the animation: <http://vimeo.com/242086634>



Image 16: Selected frames of the final composited result of the animation

5. Summary

After this thesis work, and previous experience of simulating hair, I definitely think that 3D hair simulation is time consuming-process that, besides good problem-solving skills, patience and understanding of the techniques used, involves good planning and understanding of the wanted motion. It defines lots of the character's style. Whether to use it or not defines some of the project look and use of resources.

Generally, the end result of the hair simulation for this thesis was successful. Hair looks and moves nicely and fits for the character style. If I would take the look further, to make it better, I would have to make the hair better starting from the modelling. Next paragraphs, I'll go through some of my thoughts of making the hair simulation.

To be able to achieve really nice hair simulation it has to have well modelled base curves. This affects to the whole hair simulation, look and movement. In my scene base curves were modelled quickly to be able to move quickly forward, because I had all the other time consuming steps in my mind. This is why the end result is littlebit sloppy especially in the root. Lower curves bend out too much from the root so that they don't stay under the top curves. This is not a massive problem in

curly hair, but it's not how hair would generally grow. It definitely has its impact to the hair look and movement.

I think hair movement is still a little bit stiff. It's really difficult to achieve flowiness, swing and realistic setting time for the movement, at least with this kind of really simple hair rig. I had to do lots of editing in the dynamic simulation settings, to make the end result to have enough control. It took me many hours and couple of good night sleeps to end up to the final settings. There is many ways to set up attribute values to get nice or needed end result. Even after deciding the key attributes to control the hair's dynamic features, it still took lot of time to finetune the movement. If I would continue to make the movement better, without adding anything to the rig, I would start to keyframe some of the dynamic qualities during animation to achieve better physical qualities for the hair at specific time of the movement, like less stiffening bend links when the movement has started and the hair strands have achieved to stay generally together.

The animation look is cute and soft. Hair style, color, strand thickness, amount and movement all go together with the general style. I could have achieved nicer rim light, but I would have had to add more lights into the scene.

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