Deer: Creating a Realistic 3D Animal Using Photogrammetry

Karie Carita
klc7939@rit.edu

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Deer: Creating a Realistic 3D Animal Using Photogrammetry

By Karie Carita

A Thesis submitted in partial fulfillment of the requirements for the degree of

Master of Fine Arts in Visual Communications Design

School of Design | College of Imaging Arts and Sciences
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Thesis Committee Approval

Chief Thesis Adviser:
Prof. Daniel DeLuna
MFA Visual Communication Design

Signature of Chief Thesis Adviser       Date

Associate Thesis Adviser:
Prof. David Halbstein
3D Digital Design

Signature of Associate Thesis Adviser       Date

Associate Thesis Adviser:
Prof. Alejandro Pérez Sánchez
3D Digital Design

Signature of Associate Thesis Adviser       Date

MFA Thesis Candidate:
Karie Carita

Signature of MFA Thesis Candidate       Date
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Abstract
Abstract

Creating a 3D animal using the process of photogrammetry can bring more realism to a user’s game experience.

In the 3D world, there are various ways for creating animals in video games. Specifically, quadrupeds are known to be very challenging. Since technology is evolving every day, there are always newer ways of creating video game assets. It is challenging to have complex model details and also have smooth real-time rendering in a game engine.

Photogrammetry can capture exact details of a real world animal and incorporate them into a 3D asset. The purpose for using this process is to create a realistic 3D animal for use in a game. Animals are often secondary characters in video games, but adding details to such characters adds to the overall experience for the user.

The purpose of the project is to find a way to utilize photogrammetry so as to meet the wants of the target audience (gamers). To many, realism is important for not only the primary character in a game, but also the secondary characters.

Keywords: 3D, games, animation, deer, animals, realism, video games, photogrammetry, rigging, fur, texture, rendering, Maya.
Photogrammetry is not extremely common in the video game industry, however it does occasionally make an appearance. Due to many studios keeping their methods private, it is not always entirely clear as to how some characters are created. This makes researching the subject quite difficult. There is evidence that photogrammetry is used in some elements of video games, such as foliage, ground textures, and man-made objects (pots, furniture).¹ As far as animals, there are no photogrammetric models available that are appropriate for in-game use. They are very high in polygon count and are not utilized for real-time rendering.

The use of photogrammetry for creating primary and secondary characters could really generate a realism boost in video games. Upon researching how gamers feel about realism within certain games, it is clear that most want secondary characters to be just as detailed and realistic as the primary character. These secondary characters could include animals, steeds, or other human characters that are interacted with.

This project focuses on using photogrammetry to create a secondary character (deer) to be used in a game engine.

The use of photogrammetry to create a realistic deer for use in a game engine can pave the way for future game character development.

The goal of this thesis is to create a realistic 3D model using photogrammetry along with the combination of rigging, animation, texturing, and fur. The idea is to utilize the process of photogrammetry as much as possible in order to obtain a realistic model.

Problem Statement
Addendum to Thesis Proposal

- Changing from a horse to a deer
- Photogrammetry on a non-living animal instead of a real animal
- An addition of an environment
  - A base underneath the final character for the showcase render
  - Foliage and rocks added to the scene to help showcase the deer in the game engine
- Additional renders
  - Models without textures
  - Models with wireframes
The initial idea for this thesis project was to obtain a 3D model by conducting photogrammetry on a living horse. The horse was not to be sedated but simply stand in an open space, such as an arena, while pictures were taken. As little tack as possible was to be used to keep the horse in a standing position so as to limit any unnecessary geometry that might be created with the photogrammetry software.

Three separate trials of taking photographs were done with the horse. Each trial consisted of taking 300 photographs on average and then uploading them into Autodesk ReMake for processing. Two of the three trials took place with the horse indoors and one of the trials took place with the horse outside. All three trials were unsuccessful with obtaining a useful model. It was understood that any model generated with the photogrammetry software would not entirely be perfect. However, the hope was to obtain a model that would be a starting point and then later polish up in a 3D editing software.

Other issues with using the horse also arose during the photogrammetry process. One possible reason for the lack of success was the color of the horse. Since the horse was white, it reflected light which may have negatively affected the processing of the images in the photogrammetry software. Unfortunately, the use of another horse wasn’t an option at the time. The second and most likely reason for the lack of success was probably due to the fact that it was a living horse and would move out of position frequently.
While obtaining images for use in photogrammetry, it is important that the object does not move so that the software is able to triangulate the object in the images and then create a model in 3D space. Even though the horse was well-behaved, he would still move his feet, take a step, or bob his head occasionally which were all natural horse habits. Unfortunately, this complicated the process drastically.
Idea Evolution

To stay consistent with the overall idea, photogrammetry was conducted on a different animal that was also real, but unmoving. In place of a living horse, a taxidermy model of a deer was used instead. Since taxidermy revolves around the idea of keeping animals looking realistic and alive, even after death, it became a viable solution for obtaining a 3D model. Even though the deer had glass eyes and was stuffed with styrofoam, it was all covered up by its real pelt and altogether it looked completely like it would have in the wild (see Figure 1).

Further along in the process, different aspects of the project evolved into different ideas, such as software usage. There were other minor adjustments along the way, such as the setting choices when using the XGen plugin with Maya to generate hair. At one point, guide curves were used but after a few failed attempts at exporting them out, the grooming attributes were used instead.
Figure 1. Taxidermy deer
Research
The target audience for this thesis project was young adults who were avid gamers. This project leaned towards gamers who tended to play video games that mimicked real-world elements. Two examples would be Red Dead Redemption and Assassin’s Creed. Both games consist of a primary human character that interacts with multiple secondary characters which range from other humans, steeds, or various other animals.

When people play video games that depict real-world environments, it’s important that the level of detail is not solely focused on the primary character, but on the secondary characters as well. In Assassin’s Creed, the primary character is relatively detailed, yet the horses in the game that he rides from one city to another seem to lack in detail. Even though they are not the primary focus, it’s still important to the overall experience of the game.

To determine how others thought of this concept, a questionnaire was conducted of a small group of people who regularly played video games (see following page).
A questionnaire was conducted of young adults who regularly played video games (Figure 2). This group consisted of people ranging in age from 25 to 34 years old. The idea was to gather their insight on how they felt about realism in video games and the importance of detail between primary and secondary characters. It was understood that this survey did not pertain to fantasy games, but only games that depicted realism in comparison to the real world.

1. *Do you enjoy playing video games that are realistic and mimic real-world details?*

100% of the people who were asked this question wrote ‘yes’ as their answer.

2. *Do you pay attention to the level of realistic details on the primary character?*

Out of the people who were asked this question, 89% said ‘yes.’

3. *Do you pay attention to the level of realistic details on the secondary characters?*

Again, 89% of people stated ‘yes’ for this question.

4. *Do you care if the level of realism in the secondary characters is the same as the primary characters?*

89% of surveyers said ‘yes’ to this question as well.
Although this was a small test group, it was determined that people who regularly played video games were aware of the realism and the attention to details for all characters in a game. Some people from this group played video games more often than others in the group. A few of the group members were also more fussy about details than others. It was important to find a range of different gamers.
Video Game Survey

This survey pertains to video games that try to depict realism in comparison to the real world. Two examples would be Red Dead Redemption and Assassin’s Creed. These games consist of a primary human character interacting with various secondary characters.

Primary Character: the main controllable human character
Secondary Characters: animals, steeds, and other human characters

Please answer yes or no to the following questions:

1. Do you enjoy playing video games that are realistic and mimic real-world details? ______

2. Do you pay attention to the level of realistic details on the primary character? ______

3. Do you pay attention to the level of realistic details on the secondary characters? ______

4. Do you care if the level of realism in the secondary characters is the same as the primary character? ______

Thank you for completing the survey. Your answers will remain anonymous.

Figure 2. The Survey
Personas

Ricky Harrington, 29

Hometown: Cutchogue
Occupation: IT

Figure 3. Male persona
**Personas**

Aspyn Hayes, 25

Hometown: New York City  
Occupation: Student

*Figure 4. Female persona*
Video. This video talks about the use of photogrammetry in the film War Horse, directed by Steven Spielberg. Two live horses were used as the main character’s horse. To keep the movie as authentic as possible, Spielberg wanted to use live horses as often as he could, however two scenes in the movie required the use of CG models. The scenes were too dangerous for the use of live horses. The two horses that both played the main horse, were used for photogrammetry in order to create a somewhat genetic cross between them for the final CG model. The final shots of the two scenes with the CG model are absolutely stunning and look extremely realistic.


Product. The Megascans library through Quixel is an extensive database of various kinds of assets made from the process of photogrammetry. With a monthly membership, various 3D assets and texture maps can be downloaded for use in renders or game engines.
Article. This article talked about the use of a pair of images taken from two synchronized cameras of animals in the wild. The animals were too dangerous to approach so the process was from a reasonable distance. With the pair of photographs, the process of photogrammetry was used in order to obtain measurements of the animals. The idea was to avoid immobilizing or anesthesizing any of the animals in order to obtain the measurements needed. First, the traditional method was used up close and then the method of using the synchronized cameras at a distance was used. The first trials were used on an approachable animal, such as a cow, and once any margin of error was discovered, which ended up being minimal next to none, the process was taken and used on the wild animals.

Video. This video depicted an original invention of a physical rig that had four cameras attached for the purpose of photogrammetry. The method of taking photographs on multiple cameras at the same time proved to be quite useful and accurate for the final outputs. The project focused on the use of small reptiles and amphibians only and nothing larger. These animals were chosen because they were less apt to move around while the process of collecting photographs was underway.


Product. This website sells highly realistic 3D models of animals, people, environments, and miscellaneous items that have been created using photogrammetry. The models of animals consist of dogs, birds, insects and skulls. Most of the models come with textures but do not have any rigs. Only one model is specified as being game-ready and that is a model of a deer skull. No other models are considered game-ready. The models appear to have very dense geometry which is most likely the reason as to why they can’t be imported into games.

Book. This book is designed to show artists the intricate anatomies of select animals and how they move. The main focus with this book is the level of detail that is provided about horses. The detailed drawings show information about muscular structure, skeletal structure, and what different parts of the body are called. It has detailed figures showing different orthographic views of the horse. This book will really help with the overall anatomy and how to properly show movement using an accurate muscular setup. It will also help with the initial placement of edge loops on the model of the horse that is created.


Tutorial. This video gives an in-depth tutorial on how to effectively create realistic looking hair for a model that will be used in a game engine. The purpose of this video is to create hair using geometry so that the game engine can easily render it in real time as a player is playing the game. Guides can be converted to surfaces and then from there to flat cards. Maya 2017 actually comes with a small library of hair textures that can be used for characters that are meant for games. These textures are assigned to the cards and have an alpha which makes them look like hair. The library is under Maya 2017 > Presets > Textures > Assets.

Tutorial. This is the second half of the tutorial that gives a step-by-step instruction on how to create realistic looking hair and use it in games. This portion of the video shows how to use XGen to directly create geometry from the hair curves. Increasing the width of fewer density strands gives the illusion that there is more hair present than there actually is. The card instances can convert XGen primitives to polygons which will then be more efficient for games.


Tutorial. This video covers blend shape editing using the new editor introduced in Maya 2016 extension 2. This editor makes it easier to create blend shapes on the fly for characters that are already skinned. This tutorial shows how to create blend shapes without having to make duplicates of the original bind pose mesh. Different bind poses are easier and faster to duplicate and mirror to get more options with the character.
Tutorial. This video shows how to use a system that will do corrective blend shapes on characters that have already been skinned. The purpose is to help specific poses that might have problems when a character moves a certain way. The pose interpolator is the logic that will be behind the functions of what the pose editor does. Using these tools, muscle deformations can be created to capture a realistic look in a horse. The steps in this video are very easy to follow.


Tutorial. This video goes over the steps on how to connect the animation rig with the bind rig. It is an important step when creating a character that will be required to move in different poses. It also goes over the steps for creating set driven keys to help make it more seemless and easier for the animator. The horse will have an animation rig and a bind rig so this video will really be of great use.

Tutorial. Skin weights will be necessary to the project in order to get the realistic motion that is intended. This tutorial will be essential to help with debugging any problems that might arise. The only downfall with this tutorial is the narrator is a little hard to understand at times but this video will mainly be used as reference and to double check work and not so much to follow along minute for minute. The purpose of the skin weights is to effectively prevent any unneeded geometry from moving when the joint is rotated. This will prove most effective with the horse’s walk cycle.


Tutorial. This video goes through setting up animations, baking them, and exporting/importing to Unreal Engine. The tutorial goes over different settings needed to prepare the model and animations for being exported. This shows how to export from Maya and also how to import into Unreal Engine with the appropriate settings. Different blueprint setups are required to get the animation to play properly within in Unreal Engine.

Tutorial. This tutorial goes over techniques for rigging specifically quadrupeds in Maya. Athias teaches the viewer how to create complex flexi systems and controls that help with animating a quadruped in a very realistic way. He also utilizes Maya’s IK handles and certain scripts to help increase the productivity of the user’s workflow. To further create realism in the model, he uses blend shapes as corrective targets and pose trackers to help bend the animal’s limbs properly.


Tutorial. Athias goes over how to properly set keyframes for a looping run cycle animation. This tutorial goes over the fundamentals for utilizing Maya’s animation preferences and then onto creating a believable run cycle.

Tutorial. In this tutorial, Gend goes over the process for creating fur on an animated mesh. He uses the grooming system within XGen to create a believable look and then incorporates real-world attributes such as wind and turbulence to further perfect the look of the animation.


Tutorial. This video starts by going over the basics of creating alembic cache files out of an animation in Maya. It introduces different tidbits that help the user understand certain settings within the alembic cache options and how to get the best output from those settings.

Tutorial. This video explained the uses and advantages to using polygons as hair for use in game engines. With the right textures and shaders applied within a game engine, polygons can serve as a better alternative than using actually hair curves. This tutorial went through the steps for creating hair and then converting them to polygons.


Tutorial. This video goes over how to use a newly released software called Handplane Baker. The tutorial covers the basics in terms of what settings to set and how to get the most out of the software. It is a free software and it's very useful for creating and exporting out various types of maps for 3D objects.
Camiolo, Vince M. “Elk vs. Photographer | Great Smokey Mountains National Park.” Filmed [November 12, 2013]. YouTube video, 07:00. Posted [November 12, 2013]. https://www.youtube.com/watch?v=vGQExgOxZMQ&index=3&list=PLAohxCOpxAsyfwYJ3adMPkyMXk2DmAmp&t=189s.

Video. Only the last forty seconds were needed from this video. This footage came in handy because it was useful to watch an elk that was a similar size to the taxidermy deer. The elk in the video walks across the screen and it proved very useful when animating the 3D model. Different elements of the elk, such as the steps, muscles, and head motion, were watched closely so as to incorporate this in the animation walk cycle.


Website/Product. This website showcases a variety of taxidermy models. This location was where the photographs of the deer were taken. The owner was very kind and was interested in the scope of the project that was being conducted. He did not demand any compensation for the amount of photographs that were being taken.
Influence on Process

The main goal for this project was to create a realistic model of a deer for use in a game engine. There were many factors that needed to be considered: the photogrammetry, the skeletal rig, how best to animate the deer, what kind of textures to use, and how best to apply the fur. All of these factors needed to be considered in order to create a realistic game character.

Obtaining the model through photogrammetry was only the beginning for creating a realistic animal. Upon researching what methods others had used with photogrammetry on animals, it was inspiring to try and create a workflow that would suit the needs of the project. Since the use of photogrammetry on animals has been used for films before, it was interesting to see little to no use of this process with game assets, especially animals. The goal was to see if photogrammetry was a decent option for starting the process of creating a video game character.

One of the longest parts of the process was the rigging stage. The rig needed to be complex enough so that it could later be manipulated to create a believable animated walk cycle.
With the help of tutorials, a complex rig was constructed with the use of flexi systems. The flexi systems were only needed along the length of the body from the chest to the hindquarters and also another one through the length of the neck. The purpose of these flexi systems was to create a believable twisting motion of the body and neck as the animal moved in the walk cycle. There was an advantage and disadvantage for using these flexi systems. First, the advantage for using them was that it drastically improved the overal believability once the animation was completed. However, the downfall for using the flexi systems was that they were not entirely connected to the root joint of the main skeletal system throughout the deer. This later caused issues when it came time to importing the model into Unreal Engine, but exporting the animation as an alembic cache was able to solve this hurdle.

In order to better create realism with the deer, fur was a necessary attribute that needed to be added to the model. The main issue with fur was figuring out a way to cut down on any lag time in a game engine yet still maintain as much detail as possible.

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Since Autodesk Maya was the primary software being used, it made sense to use XGen as the method for generating fur along the deer. The hope was to create the hair and convert it to polygons in order for it to run smoothly in the game engine. Troubleshooting became a constant nuisance as work on the fur commenced. Although the fur groom looked up to parr when rendered out in Maya using Renderman, much of the details had to be lost when imported in the game engine. Even though the density of the fur was scaled way down to compensate for real-time rendering, it took much of the desired details away from the overall look. This was disappointing.

There are many approaches to creating a game character, but the quest for finding the perfect workflow while using untraditional methods was intriguing. At the end, it was discovered that the methods chosen weren’t necessarily the best.
Process
Photogrammetry

Photogrammetry is the process of triangulating an object’s location in multiple images and generating a 3D mesh. For this project, two trials were conducted for taking images of the taxidermy deer model.

Technique

There were two trials that were conducted at separate times, each trial consisted of taking upwards of 300 photographs of the deer. Autodesk ReMake (now Autodesk Recap) was the software that was chosen to generate the 3D model and it specified that a maximum of 250 photographs could be used for each generation of the model. The goal was to take as many photographs as possible so that there were a lot to choose from when importing into the software (see Figure 5).

While researching others who had used photogrammetry with animals, many had used more than one camera to take multiple photographs at once. While this is ideal for capturing as much as possible, it was hoped that decent results could be obtained with just the use of one camera. For this thesis project, a single, professional Nikon camera was used to capture images for each trial. Being able to obtain a model using photogrammetry with the use of one camera became somewhat of a side goal.
Figure 5. Photogrammetry images
Although using one camera for photogrammetry was doable, it proved to not be completely ideal. While photographing the deer, it was necessary to try and capture as many angles of the deer as possible for all 360 degrees of the animal, including the top and bottom of it as well. With one camera, it was tedious work to make sure all the photographs encompassed every bit of the deer.

Lighting became another issue, but was eventually resolved. During the first trial of photographing the deer, it was in the late morning and because the deer was situated so that one side of it faced a large window, its fur was very illuminated on one side. This became a problem when it came time to importing the images into the software. One side of the deer was over illuminated and the other was cast with normal light. To fix this issue, a large flashlight was brought for a second trial and it helped immensely. Other issues involving the textures arose later on in the project.

**Sculpting**

In most cases with photogrammetry, the models that are generated are almost never perfect (see Figure 6). Once the model is created, it needs to be given some attention in another software to patch up any imperfections. However, it is important to keep the overall shape since that is the point of photogrammetry.
Figure 6. Photogrammetry model
Sculpting

Even though there were two trials for taking images, there were many trials done for generating a model using the software. Some of the models had areas that were more detailed than others. One good model was all that was needed, but it would first require taking pieces of various models and putting them together in one. The antlers were taken from two different models and combined in a group. Another model was used as the body.

For this thesis project, the photogrammetry model was brought into ZBrush for refinement. Since the taxidermy model was attached to a base, that was also captured in the 3D model. The first step was to eliminate the base.

Most of the attention for fixing imperfections was directed towards the main body of the deer. The antlers were added later. Once in ZBrush and the base was removed, the mesh was polished up, smoothed out, and geometry was added to close holes where it was needed. The same process was then applied to the antlers. From there, the body was brought into Maya along with the antlers and was further inspected for imperfections (see Figure 7-8).

Further sculpting was done in order to regain some of the details that were lost after initially polishing up the model and fixing geometry. See the texturing section for more details (page 61).
Figure 7. Side view of photogrammetry model in Maya.
Figure 8. Front view of photogrammetry model in Maya
Refinement

In order to help make the rigging process smoother and easier, it was necessary to have a model that was symmetrical.

Temporary joints were added and skinned to the head and neck so that they could be straightened out along the axis. Once this was accomplished, the model was cut in half and its right side was deleted. Another set of temporary joints were added to the foreleg in order to straighten it out into a standing position. The hindleg was already rooted to the ground so it was not necessary to add joints to it. Once the leg was straightened out, the model was polished up, mirrored, and then combined to form one symmetrical model of the body.

The antlers were made up of two separate pieces that were taken from two separate photogrammetry generated models. The two pieces were then placed above the head of the symmetrical deer model in their rightful position and then mirrored across to the other side to form one large set of antlers. The model was then fully symmetrical (see Figure 9).
Figure 9. Final Symmetrical Model.
Retopology

Retopologizing is the process of changing how the polygons flow over a 3D model.

Anatomy

This process ensures that certain edge loops are placed along specific areas that will define important movement points when the character is rigged and animated. In this project, such movement points were areas where muscles would be more defined when the animal moved certain joints. These muscles included the ones close to the scapula, humerus, and femur bones.

Now that a symmetrical model was created, the next step was to prepare it for rigging. Deer move a certain way due to the makeup of their anatomy. For the 3D model, the direction of edge loops along certain areas of the body were very important in order to mimic the motion of a real deer. It was important that the edge loops around the shoulders and the hindquarters followed closely with the muscular structure of a deer. Genuine anatomy references of a deer became extremely important in this stage of the process.¹

With proper anatomy references, it was possible to determine the best placement of edge loops and thus plan accordingly for retopologizing the model in order for the deer to be rigged and animated effectively (see Figure 10-11).

Figure 10. (top) Final geometry layout.  
Figure 11. (bottom) Highlights the important edge loops needed for proper rigging and animation.
UV Creation

UVs are important and necessary in character development because they are needed for applying textures accurately and effectively. At this stage, ZBrush was used to generate UVs for the deer model. The UV map included the deer’s body and antlers. The eyes would be modeled later in Maya and UVs would also be created. The UVs for the eyes, antlers, and body would eventually be contained onto one map and then exported for use in a texturing software (see Figure 12).
Figure 12. UV layout for the eyes, antlers, and body.
Rigging

Rigging any character can be a long, arduous process that takes a lot of patience. This is especially true when the goal is for end result to mimic real-world movements. It was again important to follow references of anatomy so that the skeleton would accurately move the character once animated.

Flexi System

A total of two flexi systems were needed for this model. The reason for the use of these flexi systems was to specifically help with the movements of the main body (from the chest to the hindquarters) and the neck. Their design was to help with certain motions that would be harder to achieve with regular joints, such as twisting and bending. The flexi systems would not entirely be connected to the main skeletal rig, but they would help drive part of the rig for animating.

See Figure 13 for the identification of the flexi system. Each flexi system was made up of five joints (C) with square controls around them for easy selection. These joints were parented to a plane (B) that would be visually helpful in determining the direction of the joints’ movements. There were three square controls that were along the body of the system. One was the start control (A), one was the mid control (D), and one was the end control (F).
When applied, driven keys in the attribute editor were turned on or off so that the end control would drive the mid control, which could then drive the start control. Once those were in place, a global node (E) was created to group everything together for easy selection of the entire system.

Once the skeletal system was created, one of these systems would be placed along the body with the start control at the chest. The other flexi system would be placed along the neck with the start control at the head.

The flexi systems were helpful in making it easier to bend larger areas of the body. However, it was later determined that this wasn’t completely necessary for a simple walk cycle. In the future, if a run cycle was ever needed for the deer, the flexi systems would certainly come in handy since they would help animate a heavier motion. It was also discovered later on that the flexi systems did pose issues when the model was ready for the game engine. Unreal Engine has strict parameters when importing characters and skeletal meshes. One parameter is that only one skeleton is accepted. Technically, the deer model consisted of three skeletons according to Unreal Engine’s error messages because of the flexi systems. Fortunately, a method around this was discovered that made the deer importable. This information can be found in the animation section (page 58).
Figure 13. Flexi System
Skeleton

Using anatomy references, the joints were placed strategically so the deer would move as accurately as possible.¹

See Figure 14 for joint identification. The following joints were applied to the deer in their appropriate placement: (A) scapula, (B) head, (C) tail chain, (D) ear chain, (E) thorax, (F) pelvis, (G) radius, (H) metacarpus, (I) front hoof, (J) femur, (K) tibia, (L) metatarsus, (M) rear hoof, (N) humerus. A mastor root joint was created to bind the chains together but was kept hidden throughout the process so as to not look confusing. The flexi systems are seen in Figure 14 also after being integrated into the main body and the neck regions.

IK handles (inverse kinematic handles) were then added along the legs to help create a range of motion for animating. These IK handles stretched from the humerus to the hoof on the front leg and from the femur to the hoof on the hind leg. This handle made it easier to grab the entire chain of joints and move them that way instead of rotating the joints individually.

Only one side of the skeleton would be created and lined up with the deer mesh. Then lastly, the joint chains would be mirrored to the other side. At this point, the antlers were parented to the head joint to ensure they would move along with it.

Figure 14. Skeletal System
Skinning

Skinning consists of binding the mesh with the skeletal system. This ensures that the deer will move based on the movements of the relative joints in the chain.

Once the mesh and skeleton are bound, paint weights for each joint must be applied so the mesh deforms properly when a joint is rotated. Weight painting is a long process that takes time if a certain result is desired. Since this project revolves around realism, it was important to make sure the deer’s skin deformed properly for each joint. While applying paint weights, it was often necessary to rotate a joint away from the bind pose in order to see how the joint was reacting to the painted weight. This would often give a clue as to what further weights needed to be painted in order to create more realistic bends in the deer’s different extremities.

Blend Shapes

A blend shape helps a specific portion of the mesh to conform to a predetermined shape. A common use for blend shapes is muscle flexion and extension.

The next step was to apply blend shape deformers to specific areas that needed attention. For the deer, when it lifted its front leg, the muscle along the radius would bulge slightly because it was being flexed.
A similar phenomenon would happen for the hind leg. Once these blend shapes were applied to the upper foreleg and upper hind leg muscles, they became keyable for animating (see Figure 15).

Once the blend shapes were created, it was time to set up a way to trigger them automatically whenever the leg raised. Although this wasn’t a necessary step, it made it easier with animating so that there was one less attribute to key while creating the walk cycle. To create this, the use of pose trackers would be needed which would be driven by specific joints (see Figures 16). The pose trackers were made up of a variety of spheres. The white spheres (A) were for alignment purposes. The goal object (B) was intended to be the target for when the blend shape would be at its highest value. This would only occur when the focus object (C) was within the global object. The focus object would require being constrained and parented to the metacarpus in order for it to work. The addition of driven keys would ensure that every time the leg was lifted and the focus object entered into the space of the goal object, the blend shape would increase in value. One integrated into the mesh (Figure 17), the pose tracker could be hidden from the scene to reduce clutter. This system was applied to all four legs.
Figure 15. Blend shapes in the foreleg
Figure 16. (top) Tracker system
Figure 17. (bottom) Tracker integrated with the model
Jiggle Joints

Adding blend shapes to define muscle flexion and extension really added realism, but the addition of jiggle joints made it go a little further with believability. When an animal walks, there are muscles that can appear to jiggle or twitch during that motion. While watching footage of an elk for reference, it was no exception.¹

There were a total of four single joints that were created in the areas that they were needed. Two of the joints were placed behind each humerus bone and the other two were placed next to the femur. These joints were then added as influence to the bound skin and paint weighted just like the others. They were placed in these specific areas because they were significant when the deer walked. These designated areas were predefined during the retopology process so that when the jiggle joints would be applied, they would deform properly. See retopology section for more information (page 41).

¹ Camiolo, Vince M. “Elk vs. Photographer | Great Smokey Mountains National Park.” Filmed [November 12, 2013]. YouTube video, 07:00. Posted [November 12, 2013]. https://www.youtube.com/watch?v=vGQEx-gOxZMQ&index=3&list=PLAohxCOptxAsyfwYJ3adMPkyMXk2DmAmp&t=189s.
Refinement

At this point in the process, the main rig was complete. An addition that would help make it easier to animate would be a series of controls. The main purpose of controls is to help select an area of the model and animate it more easily.

A total of fifteen controls were created (see Figure 18). A large control was created for each of the smaller controls within the flexi system: one for the end control (B), one for the mid control (C), and one for the start control (D). Two controls were created to help animate the tail joints (G), four controls were created to drive each of the IK handles (F), and one control was made to drive the neck (E). A control was also added to easily animated the jiggle effect (H). The final control that was created was for the center of gravity (A). This control helped drive the entire deer directly from the pelvis (see Figures 19-20).
Figure 18. Entire rig system
Figure 19. (top) Center of Gravity control inactive
Figure 20. (bottom) Center of Gravity control active
Key Placement

A total of twenty-eight frames were used for the entire animation in order to create a looping walk cycle. The first and last frames were identical.

To start, a total of seven key positions were placed at intervals of every four frames. This method was used to simply block in a rough animation sequence (see Figure 21). Once these initial positions were blocked in, extra keys were added as refinement in between these seven positions to help give the deer a smoother motion. Once the walk cycle was completed, the controls for the body flexi system were used to add to the overall look. First, the end control was animated so that the deer’s hindquarters would rotate and bob slightly whenever a step was taken. Second, the start control was animated so that the deer’s shoulders appeared to rotate and bob slightly. This added tremendously to the realism of the overall walk animation. Lastly, the head and neck region were animated so it appeared in-step to the legs. This final addition really brought the entire animation to the next level of believability.
Figure 21. Key positions
Output

After the walk cycle was complete, it was time to decide the best way to export the animation. All that remained was the application of textures and fur. It was decided that the best way to proceed was to export the animation as an alembic cache file and then from there be imported into a new scene file for the textures and fur. The reason for this decision was the knowledge that alembic files can be read by various programs, including game engines. It seemed the most logical choice before proceeding. The other reason for creating an alembic cache was to eliminate all of the rig elements from the scene so they would not be in the way visually when applying the textures and fur.
When using photogrammetry to obtain a 3D model, it is common practice to utilize the textures from the object that was captured. With the taxidermy deer, many issues arose in regards to the textures from the real model. Since the lighting was mediocre when the photographs were taken, even with the addition of a light, much of the deer's fur appeared as different shades in many of the images. Also, there was not one single model that was used from the photogrammetry software. As mentioned before, three separate models were used so as to take nicely detailed segments from each. Because of this, the actualy taxidermy textures could not be applied properly.

As a solution for this, the textures were used for reproducing the fur by reproducing them in Adobe Photoshop and creating custom textures. Also, with the help of a texturing software called Quixel Suite, a deer fur texture was used to help compensate. This also led to the decision to add actual fur to the model since the textures couldn’t be properly pulled from the photogrammetry images.

Maps

To create the overall color of the deer, antlers, and eyes, an albedo map was created using Quixel Suite. The texture on the body was initially created with the idea that it would act as the “skin” of the deer which would be underneath fur. Later on, it a texture that would compliment the fur instead and somewhat blend with it. This method would also create the illusion that more hair was present than actually was.
Also, the amount of hairs created on the surface of the model would create render lag not only for Maya but also for Unreal Engine. Therefore, using a fur-like skin texture along with a smaller density of hairs could create the overall realistic look that was being sought out. To see the various maps, see Figure 23).

To create the normal map, some sculpting was done using ZBrush in order to bring out some of the details that were lost from the original photogrammetry model while polishing it up. Multiple images from the two photogrammetry sessions were used to accentuate some of the details, especially on the head and hooves (see Figure 22).
Figure 22. Facial details
Figure 23. Albedo (top left), roughness (top right), specular (bottom left), and normal map (bottom right)
The addition of the fur on the deer really added to the overall look of the model. Without the fur, the model severely lacked the realistic qualities needed for the purpose of this thesis.

Method

Since this was the most complicated piece of the entire project, a very in-depth tutorial was needed to ensure proper utilization of XGen. For the method, groomable spilnes was chosen to be the subject of hair creation for the deer. Unknown at first, this ended up being the quickest and easiest method for generating hair, yet it also was extremely effective. The grooming brushes provided by XGen were extremely well constructed for creating the desired look of the fur. The actual grooming process was quite enjoyable.

Output

Once the groom itself was complete, this part of the project proved to be the most difficult in terms of output settings, glitches, and rendering. Even with external help, whether it was tutorials or written documentation, exporting any part of the various XGen attributes proved to be quite confusing and inconsistent.

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To prepare for the game engine, it was decided that the best route was to convert the XGen hairs into polygons. However, before doing this, the percentage of density for the hair had to drastically be reduced. For the groom, the density was set to 350 and the primitives that were renderable was set to 300. This number had to decrease drastically before the primitives could be exported into Unreal Engine. The density of 300 for the visible primitives was reduced to only thirty. Once that was done, they were converted into polygons and then exported with the model.

Unfortunately, the game engine had problems importing the model if the hair polygons were present. Often times it crashed. An idea was struck to reduce the density of primitives even further to twenty. This was more successful for the game engine, however the density was so low that they were practically not visible.

A very concerning glitch with XGen itself, was even though the groom was made and the file was saved, when the file was reopened, many times the groom would appear differently than what it did before. On the left front knee of the deer, there seemed to be an area of hairs that stuck out much further than what the groom was set for. This started to occur every time the file was reopened, even though it was not saved before in that state.
Rendering

Environments

For the final render to showcase the deer, a small base was modeled and added to the scene to help with the overall look (see Figure 24). For the lighting, a Pixar dome light was used with mild intensity and two key lights were used as well. One key light pointed towards the left hindquarters of the deer and the second key light pointed towards the right shoulder of the deer. This lighting technique was used to accentuate the fur.

It seemed appropriate place the deer on top of a snowy surface. This was done in the hopes that the coloring of the deer would contrast nicely with the base. The base was modeled in Maya and textured using Quixel Suite (see Figure 25).

For Unreal Engine, three deer models were added to the scene in a row. The first model was motionless with fur, the second model had no fur and was also motionless, and the third model was without fur but in the walk cycle animation loop.

Just like with the Maya render, an environment was also added to the game engine scene. This environment was much different because it utilized various foliage and rocks using Quixel Megascan assets.
These assets seemed appropriate for the scene since they were all created using photogrammetry.¹ These assets were placed around the showcased deer models to represent a forest floor kind of atmosphere. These assets included ferns, flowers, tree logs, stumps, and rocks.

**Still Outputs**

The final showcase of the deer model with the base was rendered out in four installments using Pixar’s Renderman and Arnold Render. The first render consisted of the final model with textures (Figure 26). The second render was the final model with no textures (Figure 27). The third render was the model without textures and also without fur (Figure 28). The final render consisted of the model in wireframe (Figure 29).

Since textures can look differently between software and renderers, it was no surprise that the deer model looked very different once imported into Unreal Engine. Although the color options were changed from sRGB to raw, just like in Renderman, they still seemed to appear somewhat washed out. The feeling of realism seemed to decline because of this. Instead of rendering out a camera animation from Unreal Engine, a screen capture software called OBS was used to capture the game view in real time (see Figure 30).

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Video Outputs

For video outputs, please visit the following links:

For the showcase render:

https://youtu.be/jfLp2Hh3kNM

For the game footage:

https://youtu.be/8XHA8vHsRhk
Figure 24. Final model with base
Figure 25. Albedo (top left), metalness (top right), roughness (bottom left), and normal map (bottom right)
Figure 26. Final model
Figure 27. Final model with no textures
Figure 28. Final model with no fur
Figure 29. Final model with wireframe
Figure 30. Final model in Unreal Engine.
Finalization
Benefits

The methods taken to complete this project have definitely inspired new ideas for future projects. Even though certain paths were taken that didn’t always work the way they were intended, it still brought about ideas for new questions that hopefully can someday be answered.

After completing this project, a deeper understanding of the different processes used has been gained. Even though certain things could use considerable refinement, the knowledge from the journey has still been earned.
Future Iterations

There are definitely other technologies that deserve to be explored, no matter what process of this project is being discussed. Whether it be rigging techniques or fur techniques, there is still more to learn and methods to try out.

With a limited understanding of Unreal Engine, it would be interesting and worth it to explore other game engines, such as Unity, for future projects such as this. Also, reaching out and networking among more general creative websites or social medias may also help for future projects.

Another area to explore is other ways of producing hair and fur for a game engine. XGen is not the only source or plugin available for Maya. A good example would be Shave and Haircut. Unfortunately, softwards such as this do not come cheap so that is definitely something to think about. Another option for the future is Nvidia Hairworks. Since not a lot of documentation could be found on this product, it was hard to try and incorporate into this thesis project without further extensive study and trials. But, it is definitely an option to try out in the future.
Conclusion
The purpose of this project was to find a new and possibly better way for creating a character for a game. Although video games have been around for many years, the technology advances so drastically. This inevitably results in the constant birth of better and easier methods for creating different types of assets. Video games are a big part in today’s society and that is not going to change anytime soon. Based on a small survey, people do care about the details of various assets in games. Any improvements are obviously always going to be welcome.

The feelings for this project are somewhat mixed since it’s completion. The final look of the deer once rendered definitely meets expectations and is very inspiring for future endeavors. However, the portion of the project that takes place within the game engine needs further inspection and research. The main goal for this thesis project was revolved around gaming, yet the deer model seemed to visually lack in the game engine compared to a traditional render. In that aspect, it is a failure.

Because of these current feelings for the project, new personal inquiries have developed because of the lingering disappointment. This disappointment has definitely sprung up new feelings of intrigue and motivation to try and find new answers to newer and older questions.
Fluid Horse

By Karie Carita
Master of Fine Arts in Visual Communication Design
College of Imaging Arts and Sciences
School of Design
Rochester Institute of Technology
September 20, 2016
Thesis Committee Approval

Chief Thesis Adviser:
Prof. Daniel DeLuna
MFA Visual Communication Design

Signature of Chief Thesis Adviser       Date

Associate Thesis Adviser:
Prof. David Halbstein
3D Digital Design

Signature of Associate Thesis Adviser       Date

Associate Thesis Adviser:
Prof. Alejandro Pérez Sánchez
3D Digital Design

Signature of Associate Thesis Adviser       Date

MFA Thesis Candidate:
Karie Carita

Signature of MFA Thesis Candidate       Date
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Abstract

Horses are complex animals and it is not easy to replicate their motion and intricate aesthetic details within a game. The higher the complexity of details there are on a model, the slower the render time and the slower the gameplay.

Photogrammetry is a process that can be used to bring realism to many different types of objects and animals. The use of this technology could bring the right amount of detail to a model and create a better experience for the player.

There are many different types of video games that are available for people looking for a certain style. Some like fantasy while others prefer something more realistic.

This project focuses on realism. In many games, horses can be a huge part of a player’s experience. A secondary character, such as a horse, that carries a player throughout the world of the game is just as important when it comes to visual details and movement as does the primary character.
Problem Statement

The use of photogrammetry on a horse can provide a more realistic model which can then be rigged to create a fluid walk cycle within a game engine.

The video game industry is constantly releasing titles with more and more realistic assets, but there is still room for improvement. The goal of this project is to demonstrate how photogrammetry can bring finer details to a model of a horse. From there, further technical demonstrations of blend shapes, xGen, and rigging systems will show that a realistic walk cycle can be achieved using these steps.

Finally, the horse model will be ready to be imported into a game engine, such as Unreal Engine, to showcase the final walk cycle.

The addition of a highly realistic horse to a game with an already realistic environment, can really make the player become more immersed in the story. By using photogrammetry to create a realistic horse model, and then adding blend shapes and xGen attributes, it will open doors for other animal and creature assets to be created using this method for video games.
Literature Review


Video. This video talks about the use of photogrammetry in the film War Horse, directed by Steven Spielberg. Two live horses were used as the main character’s horse. To keep the movie as authentic as possible, Spielberg wanted to use live horses as often as he could, however two scenes in the movie required the use of CG models. The scenes were too dangerous for the use of live horses. The two horses that both played the main horse, were used for photogrammetry in order to create a somewhat genetic cross between them for the final CG model. The final shots of the two scenes with the CG model are absolutely stunning and look extremely realistic.


Article. This article talked about the use of a pair of images taken from two synchronized cameras of animals in the wild. The animals were too dangerous to approach so the process was from a reasonable distance. With the pair of photographs, the process of photogrammetry was used in order to obtain measurements of the animals. The idea was to avoid immobilizing or anesthesizing any of the animals in order to obtain the measurements needed. First, the traditional method was used up close and then the method of using the synchronized cameras at a distance was used. The first trials were used on an approachable animal, such as a cow, and once any margin of error was discovered, which ended up being minimal next to none, the process was taken and used on the wild animals.

Video. This video depicted an original invention of a physical rig that had four cameras attached for the purpose of photogrammetry. The method of taking photographs on multiple cameras at the same time proved to be quite useful and accurate for the final outputs. The project focused on the use of small reptiles and amphibians only and nothing larger. These animals were chosen because they were less apt to move around while the process of collecting photographs was underway.


Product. This website sells highly realistic 3D models of animals, people, environments, and miscellaneous items that have been created using photogrammetry. The models of animals consist of dogs, birds, insects and skulls. Most of the models come with textures but do not have any rigs. Only one model is specified as being game-ready and that is a model of a deer skull. No other models are considered game-ready. The models appear to have very dense geometry which is most likely the reason as to why they can’t be imported into games.

Research. A study to determine the body weight of horses with the use of photogrammetry in order to come up with better treatment options. Traditionally, the body weights were being done visually because of the animal's mass, but the use of photogrammetry proved to be an efficient and accurate way to determine body weight of a horse. Photogrammetry was used on multiple horses so as to determine whether it would prove accurate or not. The highly detailed images became useful in the overall process. In the process, the horses were scanned three times and all were scanned on the same day. The images were then compared to one another.


Book. This book is designed to show artists the intricate anatomies of select animals and how they move. The main focus with this book is the level of detail that is provided about horses. The detailed drawings show information about muscular structure, skeletal structure, and what different parts of the body are called. It has detailed figures showing different orthographic views of the horse. This book will really help with the overall anatomy and how to properly show movement using an accurate muscular setup. It will also help with the initial placement of edge loops on the model of the horse that is created.

Tutorial. This video gives an in-depth tutorial on how to effectively create realistic looking hair for a model that will be used in a game engine. The purpose of this video is to create hair using geometry so that the game engine can easily render it in real time as a player is playing the game. Guides can be converted to surfaces and then from there to flat cards. Maya 2017 actually comes with a small library of hair textures that can be used for characters that are meant for games. These textures are assigned to the cards and have an alpha which makes them look like hair. The library is under Maya 2017 > Presets > Textures > Assets.


Tutorial. This is the second half of the tutorial that gives a step-by-step instruction on how to create realistic looking hair and use it in games. This portion of the video shows how to use XGen to directly create geometry from the hair curves. Increasing the width of fewer density strands gives the illusion that there is more hair present than there actually is. The card instances can convert XGen primitives to polygons which will then be more efficient for games.
Tutorial. This video covers blend shape editing using the new editor introduced in Maya 2016 extension 2. This editor makes it easier to create blend shapes on the fly for characters that are already skinned. This tutorial shows how to create blend shapes without having to make duplicates of the original bind pose mesh. Different bind poses are easier and faster to duplicate and mirror to get more options with the character.


Tutorial. This video shows how to use a system that will do corrective blend shapes on characters that have already been skinned. The purpose is to help specific poses that might have problems when a character moves a certain way. The pose interpolator is the logic that will be behind the functions of what the pose editor does. Using these tools, muscle deformations can be created to capture a realistic look in a horse. The steps in this video are very easy to follow.

Tutorial. This video goes over the steps on how to connect the animation rig with the bind rig. It is an important step when creating a character that will be required to move in different poses. It also goes over the steps for creating set driven keys to help make it more seamless and easier for the animator. The horse will have an animation rig and a bind rig so this video will really be of great use.


Tutorial. Skin weights will be necessary to the project in order to get the realistic motion that is intended. This tutorial will be essential to help with debugging any problems that might arise. The only downfall with this tutorial is the narrator is a little hard to understand at times but this video will mainly be used as reference and to double check work and not so much to follow along minute for minute. The purpose of the skin weights is to effectively prevent any unneeded geometry from moving when the joint is rotated. This will prove most effective with the horse’s walk cycle.
https://www.youtube.com/watch?v=Glij5HdW630.

Tutorial. This video goes over the basics for the Arnold Render plugin for Maya. This tutorial was made before Arnold came with Maya by default, but the render settings are the same in most respects. This video is just an overview of how to set up the scene in order to render using Arnold. There are other videos by Solid Angle that go in depth with other attributes of Arnold that may also prove as useful. This renderer would most likely be used for the turntable animation.


Tutorial. Octane Render is a very powerful renderer because it uses the GPU instead of the CPU. It is much faster than other renderers and seems to yield a very impressive result. This video goes over the basics of getting started plus goes through how to input textures in order to yield the best results. This renderer is very good with realistic scenes and it would be interesting to see how well it works with a horse for this project. This tutorial also talks about how to use a texture input with the lighting input so the computer uses the least amount of power as possible. In other words, the textures only show up and are actually rendered where the light touches them. This is crucial when keeping render times down. This renderer would most likely be used for the turntable animation.

Tutorial. This video goes through setting up animations, baking them, and exporting/importing to Unreal Engine. The tutorial goes over different settings needed to prepare the model and animations for being exported. This shows how to export from Maya and also how to import into Unreal Engine with the appropriate settings. Different blueprint setups are required to get the animation to play properly within in Unreal Engine.


Tutorial. This tutorial is based on a software that is fairly new to the market. It was introduced during SIGGRAPH 2015 and looks relatively easy to learn. The software is designed to help artists have an easier time retopologizing models, whether they are simple or very complex. There is an entire series of videos created to help introduce the program to the user starting with how to use the interface and getting familiar with hotkeys. The other videos in the playlist go in-depth with the program and how to retopologize the model. The program is designed around the ability to draw quads on the model so that the entire process goes much quicker than 3D artists have normally done it in the past.

Tutorial. This video shows the photographs taken by Eadweard Muybridge of a running horse. Muybridge had an interest with motion and this particular series of photographs was to prove whether or not a horse’s hooves left the ground all at the same time. This video will come in handy when the animations for the horse rig are done. It will be used as a reference for the motion. Even though this video shows a galloping horse and this project will feature a walking horse, some of the movements could still come in handy, such as with the motions of the head and back.


Book. This book discusses and illustrates the different areas revolved around riding, such as skills, care, and gaits. The main use of this book will be to reference the section about the the walk cycle of a horse. It illustrates the poses of a horse’s walk cycle. The ideal way to capture the precise movements of a horse is through motion capture, but these means may not be easy to obtain or the funds available to purchase so as a last resort the keyframes of the walking animation may have to be done by hand with each pose of the horse’s walk cycle.
Ideation

• Photogrammetry
• Retopologizing
• Textures and Fur/Hair
• Animation
• Finalization
Photogrammetry

Photogrammetry is one of the main components of the project. In the beginning stages, trial runs will be done on random objects just to become familiar with the software.

Using a live horse for this project is the main goal. One of the greatest challenges that will be faced with using a real horse is movement. The horse will have to be as still as possible while photos are taken. There are a few options to possibly help with this. First, the horse will be held by a halter and rope to keep its body in the same place. Second, it may be required to prevent the horse from moving its legs by having two people holding firmly onto its front and back legs. This might keep its legs planted on the ground and not shift its weight around. This step will require multiple trials. If the use of a real horse proves to be too difficult, then a remaining option will be to use a detailed sculpture of one, such as a Breyer horse collectible.

The second challenge is the environment. The photographs to be used for photogrammetry will have to be taken indoors. The preferable spot is within an indoor arena where the lighting can be adjusted rather than using outdoor lighting that would have to be permitted by the weather.

Once the necessary photographs are taken (40 minimum each trial) they will be uploaded to the software, such as Autodesk ReMake, and produced into a 3D model. At this point, the process to retopologize the model will begin.
Retopologizing
Retopologizing the model will be necessary in obtaining a version that is cleaner and easier to work with in order to rig and animate. Another goal is to make sure the model consists of the lowest polygon count as possible to ensure render speed in a game engine is as efficient as possible.

Retopologizing a model is typically done by hand. One possible solution to speed up the process is by using a third party software to make this tedious task easier. One such software is called Sketch Retopo Software and it was recently developed for 3D artists.¹

It is important that the 3D model of the horse have proper geometry flow in order to rig it in the desired way. The edge loops must follow the muscle lines so that the blend shapes deform the skin to give a realistic look.

Figure 1 shows an outline of a horse to demonstrate the way the edge loops should fall along the 3D model. These edge loops will help with the deformations of the blend shapes to replicate the behavior of muscles. This outline contains blue and red lines. The blue lines indicate the major muscles that will have the greatest visual effect on the horse’s movements. The red lines indicate some of the more detailed muscles that help to accentuate the movements of the muscles outlined in blue.²

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¹ Kenshi Takayama, “SketchRetopo tutorial #3 (edit topology)” https://www.youtube.com/watch?v=e-C1MwUJcW4&index=3&list=PLk-A_D3Rcz0IFQv9Peyy_HC6Hqbrm5Ru.
Textures
The process of photogrammetry includes the generation of a 3D model as well as textures from the photographs taken. The software uses the actual textures of the object in the photographs to create a texture wrap around the 3D model. However, once the model has been retopologized with fewer polygons to become game-ready, the textures will then need adjusting as well. Since the mesh will have a different UV layout than when the model was first created, the textures will have to be reapplied. This can be done quite easily in Maya.

Added texture details will be hand-painted with the use of Adobe Photoshop. These will be minor details yet will create some minor asymmetry on the final model.

Some of the muscle definition will also be present in the textures. Sculpturing the model to create further details will be important to the overall aesthetics of the horse. These details will then be used as a normal or displacement map.
Fur/Hair
The mane, tail, and fur of the horse will be an added step in achieving the point of realism for the final model output. Each of these components will be created using the XGen plugin available in Autodesk Maya. A selection of tutorials will be used to follow the process of creating the hair for the horse and the process of converting the hair curves to cards will be used in order to make the model game-ready.1 This same process will be used for the fur on the body of the horse, however if it proves to be to overloading to the game engine, then the fur may be faked as a texture instead.

Animation
The next step in the project will be setting up the rig for the model. This will involve the use of a bind rig and an IK rig for the walk cycle. This step will require researching the walk gait of the horse which will be animated in Autodesk Maya.¹ The use of motion capture would be the most precise method in obtaining the realism of the horse’s walk but if this data becomes too hard to obtain or the funds aren’t available to purchase them, then manual keyframes will have to be used in animating the horse.

Once the rig is complete then the blend shapes will be added to the mesh in order to act as muscles.²

The study of the muscular structure of the horse is very important to this step. The muscular structure and placement will have to be studied closely.³

Figure 2 shows a sketch using red and blue lines to define the areas of greater and lesser importance of the muscles in the horse’s front legs. The blue lines represent the more important muscles that will define the primary shapes to be made with the blend shape deformers. The red lines represent the muscles that will help with the overall believability but will be secondary details compared to the blue outlined muscles.

Figure 3 is a sketch that shows the blue and red muscle groups of the back legs of the horse model.

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² My Oh Maya, “Maya 2016 Extension 2: Shape Editor” https://www.youtube.com/watch?v=drGGB8KJhKxM&t=3s.
Finalization
The last major step of the project will be importing the model and animations into Unreal Engine and demonstrating that the horse is fully functional and renders in real time at a relatively efficient speed. This will show that the processes used up to this point have paired together efficiently to obtain a realistic and functional model that can be used as a game asset. At this point, a video of the walk cycle of the horse will be rendered out.

The last step of the project will be creating the turntable animation in Maya but omitting the walk cycle. This will be a simple animation that shows off the final design of the model in a selected pose.

See “deliverables” section for further details.
Deliverables

• Technical
• Final
Technical Deliverables

Models
• Body (low poly version and a high poly version)
• Teeth
• Tongue
• Left eye
• Right eye

The final model of the horse will have the least amount of polygons as possible. The main goal of the project is to create a realistic model that works as an efficient asset for a game engine. If the polycount is too high, then the real-time render speed will lag yet if the polycount is too low then there is the risk of having a horse model that is not believably realistic. Two models will be created during the entire process: one will be a low-resolution model and the other will be a higher-resolution model that is created using a sculpting software in order to add extra details. To avoid using a high-resolution model within the game engine, the sculpted details will have to be baked out onto a map to be added to the low-resolution model later on. This will avoid any lag when the model is presented and used within the game engine.

The remaining assets of the model will be as low-resolution as possible and will have texture details to obtain the realism that is required for the final output.
Lighting
• Renderer: Arnold, Renderman, or Octane
• 3-point lighting configuration for final turntable animation
• Outdoor simulated lighting configuration for walk cycle animation in Unreal Engine.

The rendering engine will be determined in the final stages of the project.

The turntable animation will be a showcase piece to accentuate the final model as best as possible. Simple lighting will be used such as a 3-point lighting system to highlight the different aspects of the model. If the result isn’t satisfying then an HDR image may be created and used in order to obtain the right look.

The walk cycle animation within Unreal Engine will most likely consist of an HDR image or something that yields a similar result using the native lighting tools available within the program.
Textures
• Photogrammetric
• Photoshop
• Maps

When the photographs are used to create the photogrammetric model, the software will also stitch together the textures. The real horse that is being used is a gray gelding and that will be the resulting model that is created along with his coat color and whatever blemishes that are present. If needed, extra added details may be applied using Photoshop.

Various texture maps will have to be used in order to obtain the desired realism. Such maps may include an albedo map, roughness map, normal map, displacement map, and/or a specular map.
XGen
• Mane
• Tail
• Fur

The mane, tail, and body fur will really add to the overall look of the horse. Each of these components will be created within Maya and then be converted from instance curves to polygonal cards which will be more accepted within the game engine.¹

The greatest challenge that will be faced in this step will be the body fur. Horse body fur is usually very fine and creating lots of fur on the entire surface of the horse with the exception of minor areas may prove to be too overwhelming for Maya or Unreal Engine to handle. If this holds true, then the body fur will have to be achieved using textures to create the look of fur being present.

Mechanics
• Skeletal rigs
• Blend shapes

This step will include the creation of a joint skeleton, which will be bound to the mesh itself, and an IK joint skeleton, which will hold all the walk cycle keyframes. These two joint systems will then be bound to one another.¹

Blend shapes will be applied to areas that would normally have muscle contractions. Some of these areas are the neck, shoulders, chest, legs, and hindquarters.² Once these blend shapes are applied then further details can be added in to the texture of the horse to create the look of further definition.

Final Deliverables

Walk Cycle:
• Unreal Engine
• Walk cycle loop
• 10 seconds max
• HD 720 minimum
• Minimalist background

The walk cycle will initially be done in Maya to get all of the animations, textures, and deformations working together correctly. The main goal is to have a horse model that looks as realistic as possible both in look and motion. The secondary goal is to demonstrate that taking these various steps to obtain this measure of realism is workable after importing into a game engine, such as Unreal Engine.

The outputed video demonstration of the horse in Unreal Engine can be relatively short in order to get the point across that the model is working properly. This will be the walk cycle.

The horse model is the main focus of the project, so there will be little concern with the background. Preferably it would be ideal to keep it simple with shades of gray and not a lot of detail. If time permits it, the addition of minor background elements with the use of photogrammetry will be used.
Turntable:
• 30 seconds max
• Minimalist background
• Octane, Arnold, or Renderman
• QuickTime format; HD 720 minimum

The turntable will simply showcase the model with the finished textures and XGen elements and will not have any animations.

The purpose of the turntable is mainly to show off the textures that were created using photogrammetry. The hair and fur will simply add to the overall aesthetics but will not be animated. A specific pose may be chosen to accentuate the demeanor of the horse.

Since the model of the horse is the main focus of the project, the environment will be kept simple. However, if time permits then some finer details such as gravel or grass may be added to the scene.
Methodology

- Target Audience
- Personas
- Software
- Resources
- Hardware
Target Audience
The target audience for this project is the video game industry that concentrates their productions on PC and console games. This project's goal is to appeal towards people who work in video game studios that have a reputation for creating titles with greater realism than other studios. The main idea is to demonstrate how the steps taken to achieve this horse model could be the main process for creating future game assets.

Games are exhibiting more and more realism as time goes on and it does not go unappreciated throughout the gaming community.
Personas

Extreme Considerations:
• Fussy / Careless
• Extreme gamer / Casual gamer
• Prefers realism / Prefers fantasy

In most cases, people who work at studios that produce video games enjoy playing them as well. However, people have different things that they look for when picking out a new game to play.

Some gamers prefer to play within a fantasy world where nothing is relatable to real life. Others prefer to play games that depict real world things that they can easily recognize. Some players do not care if everyday objects don’t look exactly how they do in real life, but others are more fussy and will notice if certain details appear incorrect.

This project appeals to the people who are fussy about those minor details and enjoy being surrounded by realism in their games.
Ricky Harrington, 29

Hometown: Cutchogue
Occupation: IT

Fussy - Careless

Extreme Gamer - Casual Gamer

Realism - Fantasy
Aspyn Hayes, 25

Hometown: New York City
Occupation: Student

Fussy

Careless

Extreme Gamer

Casual Gamer

Realism

Fantasy
The photographs will be imported into Autodesk ReMake in order to obtain the initial model of the horse. From there the model will have to be retopologized either by hand or possibly a third party program, such as Sketch Retopo Software. After the model has been retopologized and reduced to a lower polygon count, it will then be imported into Autodesk Maya. A model will also be used within Autodesk Mudbox to obtain a higher detailed version to be combined with the lower resolution version via the use of maps. The texture map created by the photogrammetric process will be taken into Adobe Photoshop where minor details can be added for extra believability (if necessary). Once the animations are finalized in Maya, the finished model will be imported into Unreal Engine to demonstrate the horse’s walk cycle in action.
Resources
• Pluralsight
• YouTube
• Horse

Creating the horse to its final stage will require the use of many references and tutorials. YouTube will most likely be the main source of reference. Some of the tutorials include skeleton binding, XGen hair creation, and animation baking for use in Unreal Engine. Many other tutorials will be used as well.

In the beginning stages during the photogrammetry phase, the main component will involve the use of a live horse. Many trials will be necessary in obtaining the necessary photographs especially since the use of a live animal can be problematic. If this step proves to be too difficult to obtain the photographs necessary for photogrammetry, then a small model will be used in the real horse’s place.
Hardware

- Professional camera

The use of a camera will be necessary to complete the photogrammetry stage. It is recommended to use a professional camera because it can capture the details of the body of the horse better than common phone cameras. This will help with the believability of the finished 3D model.

If possible, the use of many cameras at the same time will be the best option.
Implementation

The project requires the use of a live horse. At least 40 – 60 images will need to be taken for each trial. A minimum of three trials will be done for taking images of the horse in order to obtain the best possible model. The software that will be used will be Autodesk ReMake. If problems arise, then perhaps a more sophisticated and professional software can be purchased such as Agisoft PhotoScan.

After the model is generated in the specified software, retopologizing the model will then be necessary. This will require a huge bulk of time in order to get the model into a rig-ready state.

The textures will be taken directly from the photos that were taken of the horse. The photogrammetry software will do most of the calculating for this process. Once the textures are completed, then the XGen elements will be added to complete the look of the model. This process will include converting the hair into polygon cards in order to be ready for Unreal Engine.

1. Kenshi Takayama, “SketchRetopo tutorial #3 (edit topology)” https://www.youtube.com/watch?v=e-C1MwU1cW4&index=3&list=PLk-A_D3Rcz0IFQv9Peey_HC8Hqbrm5Ru.
The final animated horse will then be imported into Unreal Engine where the walk cycle will be viewed and rendered out. A separate animation will be rendered out using Maya and will consist of a simple turntable animation.

The next step is to animate the model with the use of multiple joint systems and the use of blend shapes for muscles. Once that is completed then the animations will be baked onto the mesh using specific steps.

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Budget
• Photogrammetry software:
  Agisoft: $179
  Autodesk ReMake: $0
• Professional Camera:
  rent: $0 (limited time)
  buy: $700
• Autodesk Maya/Mudbox: $0
• Adobe Photoshop: $30/mo.
• Gas: $40
• Digital Tutors: $0
• Time: priceless

This is a rough budget describing the various software and hardware that will need to be used for the project. A few options are available to keep costs down. A professional camera was purchased for this project: a Nikon D3400 DSLR camera. The cost of gas will likely depend on the number of trials needed during the photogrammetry phase. The horse that will be used is boarded nearby and is relatively convenient to get to.
Timeline

- Camera trials
- Photo trials
- Model creation
- Sculpting
- Retopologising
- Rigging
- Blend shapes
- Animating
- Texturing
- Turntable
- Evaluation feedback
- Revisions
- Final renderings
- Dissemination
Contingency Plan

The greatest obstacle foreseen with this project is the photogrammetry phase of the living horse. As mentioned above, since horses are living creatures, they are prone to movement and little can be done to control this while photographs are being taken. If this step proves to be too difficult and no solution for using the living horse is found, then a small scale nonliving model will have to be used in its place. In order to continue forward with the project, the model needs has be created. Even without a living horse, as long as a 3D model is created using some type of means, then the project can continue forward as normal and still end in success.
Process

• Photogrammetry Results
Photogrammetry Results

Trial 1 Overview

Trial 1 consisted of a series of photographs (between 70 and 100). Three different attempts were made with these photographs to generate a model. For each attempt, certain photos were omitted in the hopes of obtaining better results.

The first trial session of taking photographs of the horse Willy, presented a few other problems that were not initially foreseen. Since the photo trials started in mid January, photos had to be taken in an indoor arena because the horse’s grey coat would blend in with the snow if done outside. The arena consisted of dirt footing, three walls with beige and white wooden planks, and one wall with a painted mural. The lighting had a fairly warm tone.

Being an older horse, Willy was pretty content standing still, but occasionally he would wander around the arena. One of the problems that occurred was that some of the photos were taken while Willy stood in different areas of the arena. Autodesk ReMake had some issues triangulating the images and deciphering where the horse was standing in the arena. Since three of the four walls looked almost identical, the program couldn’t create an accurate model.
Trial 1 – A

Figure 4 shows the results from Trial 1 – A. These results clearly showed Autodesk ReMake attempting to create the entire arena. There were many gaps within the entire mesh and most objects, including the horse, were incomplete.

Trial 1 – B

Figure 5 shows the results from Trial 1 – B. The resulting model contained similar results to Trial 1 – A. Some of the photos that had too much contrast or too much glare were omitted from the process.

Trial 1 – C

Figure 6 shows the results from Trial 1 – C. The resulting model contained similar results to Trial 1 – A. This trial consisted of the lowest count of images that only consisted of full body shots of Willy. No close-up photos were used. Like the previous two attempts, similar results were created.
Figure 4
Figure 6
Photographs

Figure 7 shows an image containing a collection of the photographs that were taken during Trial 1. There were around 70 – 100 photos taken that consisted of full body shots, close-ups, and details of the fur. The first trial consisted of all the photographs taken that were deemed good quality while some photographs were subtracted from the collection in order to possibly obtain better results. Trial 1 was unsuccessful.
Dissemination

i3D
Symposium on Interactive 3D Graphics and Games
Deadline: TBA for 2018
https://i3dsymposium.github.io/2017/index.html

This is a leading conference in real time 3D computer graphics and interaction. This event is held in San Francisco, California. Some of the topics include 3D game techniques, animated models, and sketch-based 3D interaction. This would be a great opportunity to showcase the Fluid Horse project.
3D Animation Design Competition
TBA 2017-2018; free
http://www.animationdesigncontest.com

This competition revolves around 3D animation. The award is aimed at good design and profound quality. The competition is open to independent designers or design studios. The winner is featured in a yearbook which is distributed amongst high-profile editors and national companies. This would be a great opportunity to show the Fluid Horse project and possibly lead to employment with an accredited studio.
Evaluation Plan

During IMAGINE RIT, a questionnaire will be provided for guests to give recommendations about the project. Some questions may include:

1. Is the motion of the model realistic to that of a real horse?

2. Does the body of the horse model look realistic?

3. Does the mane, tail, and fur look realistic compared to that of a real horse?

It is also important to get a feel for the person taking the questionnaire and to see what kind of gamer they are. Some questions may include:

1. When playing video games, would you consider yourself an extreme or casual gamer?

2. Do you prefer realistic games or fantasy games?

3. Would you say you have a greater appreciation for details in games or not so much?

Once some of these questions are answered, then the responses can be taken into account and the necessary revisions can be applied to the project.
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