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Abstract

Vulpes vulpes, the red fox, has been domesticated for hundreds of years. Through the continued breeding of the red fox in captivity, there has been an explosion of variations in color, size, and temperament. With the rise of interest in domesticated foxes as pets and educational animals, there is a dire need for education of the public on these animals and their history. Fur farming also remains a lucrative industry, an industry engaged in continuous and broad academic research. Aimed at these audiences, this academic presentation allows users to view a 30 animated fox, and select its coloration, animation, view, and review the color's genetic breakdown and history.

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DIVINE VULPINE: 3D SIMULATION OF COLORATIONS OF THE WILD AND DOMESTICATED RED FOX

By

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ABSTRACT

Vulpes vulpes, the red fox, has been domesticated for hundreds of years. Through the continued breeding of the red fox in captivity, there has been an explosion of variations in color, size, and temperament. With the rise of interest in domesticated foxes as pets and educational animals, there is a dire need for education of the public on these animals and their history. Fur farming also remains a lucrative industry, an industry engaged in continuous and broad academic research. Aimed at these audiences, this academic presentation allows users to view a 3D animated fox, and select its coloration, animation, view, and review the color's genetic breakdown and history.

INTRODUCTION

Vulpes vulpes, the red fox, has been the subject of domestication since the late 1800's, with the origins of most red foxes in captivity traced to the breeding of silver foxes, a melanistic or "black" variation of the red fox, by Sir Charles Dalton in the 1880's on Prince Edward Island, Canada (Nes, Einarsson, Jørgensen, & Lohi 1988). Though the continued breeding of the red fox in captivity, there has been an explosion of variations in color, size, fur texture, and temperament.

Fur farmers historically had a focus on coloration and fur quality, but in the 1950's, the selection of foxes bred strictly for temperament began as an experiment by Dmitry K. Belyaev by the Institute of Cytology and Genetics in what is now Novisibirsk, Russia. Belyaev's experiment entailed selecting silver foxes for breeding by their docility and lack of fight-or-flight response to human interaction. Belyaev's experiment ultimately provided a great deal of insight into the qualitative heritability of temperament as it related to physiological change reflected in the red fox (Jones 2016).

In recent years, Belyaev's research has gained a great deal of media attention, as these foxes were recently marketed to the world as evidence of domestication, dubbed by well-meaning but misinformed individuals as "dogs in foxes bodies". This is much of a misnomer as even domesticated foxes' behavior is indeed very distinct from that of dogs. The popularity of foxes as pets has risen in recent years, both due to the interest in the Siberian domestication experiment and the long running, continued practice of fox fur ranchers keeping foxes as pets and selling them to the general public (Long).

In turn, the history of foxes, their domestication, coloration, behavior, and viability as livestock and pets has been thrust into the attention of the public. Niche social media celebrity pet foxes have risen into the mainstream. "Fox villages" in Japan allow members of the public to even interact with these foxes in a petting-zoo type format (Nėjė 2015).

Fur farming also remains a lucrative industry, that also has engaged in continuous academic research on the red fox and close relatives like the arctic fox. One such example that few are aware of is that research on the ranched red fox has contributed to the widespread development and use of the distemper vaccination in dogs, lending credit to the importance of fur farming in zoology, ethology, and genetics ("The Invention of the Fromm-D Distemper Vaccine").

With the rise of interest in foxes as pets, educational animals, and research subjects, there is a need for education of the public on these animals and their history. Websites, blogs, forums, facebook groups and pages and even published books have all sprung up in attempts to educate the public on red foxes' history, behavior, and viability for captive care, both in the public education and private ownership sectors, in tangent with increased interest in the animal.

This project seeks to rise to the demand of information about red foxes in captivity. Information about the genetics, appearance, history and locomotion is presented through the use of 3D imagery, audio, and text in an easy-to-navigate user interface.

The goal in developing this presentation was multifaceted and aimed at several audiences. These audiences include fur ranchers, current and interested pet fox owners, institutions that employ foxes as educational animals, and to the general public as a means of improving understanding and positive perceptions of these animals. It also served as a means of demonstrating 3D technical skills, and the blending of two passions - scientific education and 3D art.

PROJECT RESEARCH AND CONTENT CREATION

Creation of the 3D Model

The 3D model of the red fox was created in the application Autodesk Maya 2017. In addition to researching the colorations of the fox, it was pertinent to ensure that the anatomy of the fox was as accurate as possible, within the constraints of artistic ability. Multiple real photographs, as well as anatomically accurate digital renders of the red fox skeleton and musculature, were used as direct references in the creation of the model.

To keep the red fox in scale, a box was created within the 3D development program, Maya, that shared the dimensions of the average red fox skull. These dimensions were 15cm, 7.5cm, 6cm ("Red Fox Skull)". Once the head mesh was created, it was superimposed over the orthographic photographic references of red foxes. The modeling process included functions within the program such as extruding, translating, and otherwise manipulating edges, vertices, and surfaces to fit to the references.

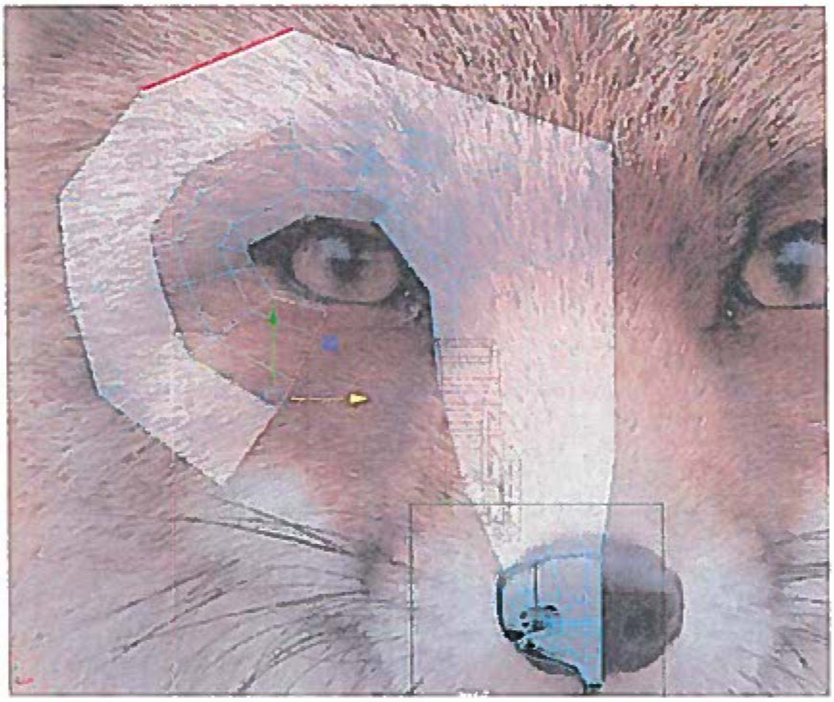


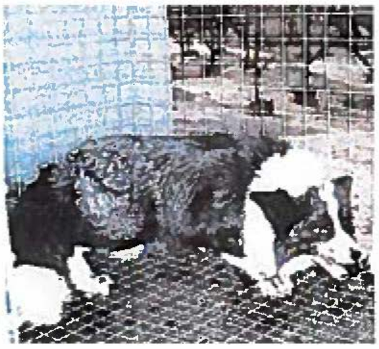
Figure 1. A digital screen capture of the process of modeling the polygons on the face of the red fox.

Texturing of the Model

There are currently well over sixty different color variations of red fox, but the project focuses on twelve common colorations. These colorations are called (1) red, (2) silver, (3) burgundy, (4) pearl, (5) amber, (6) silver cross, (7) wildfire, (8) silver whitemark, (9) platinum, (10) arctic marble, (11) georgian white, and (12) albino.

Figure 2. Twelve colorations of the domestic fox as photographed by the authors of *Beautiful Fur Animals and their colour genetics* (Nes, Einarsson, Jørgensen, & Lohi 1988); except for the Georgian white, Zoya, a pet fox photographed by her owner Kay Fedewa in 2016 in Michigan

Red	Silver	Burgundy
		
Pearl	Amber	Silver Cross
		
Wildfire	Silver Whitemark	Platinum

		
Arctic Marble	Georgian White	Albino
		

Nearly all of these photographs were taken at fur farms during the creation of the book, *Beautiful Fur Animals and their Coat Color Genetics.* The exception to these images is the picture of the Georgian white; photographed is a pet fox named Zoya from the aforementioned Siberian domestication experiment. *Beautiful Fur Animals*, even decades after its publication, remains the pinnacle of understanding the coat color genetics of the red fox.

In this book, the authors documented the physical appearance of the color mutations, investigated the history of when the colors were first documented, and presented known research about the underlying genetic factors contributing to the foxes' phenotypes. The information in the book was condensed, put in layperson terms, and presented in the form of audio and text in this project.

The twelve selected colorations were translated into what is known as a *texture,* where, in essence, color is added to the 3D object, or the *mesh* of the model. The model must first be *unwrapped,* in which the surface is laid flat to be painted on (see figure 3 for the completed UVW map used for the red fox model). Adobe Photoshop was used to digitally paint each of these colorations. Once created, the textures are imported back into Maya to be laid over the mesh.

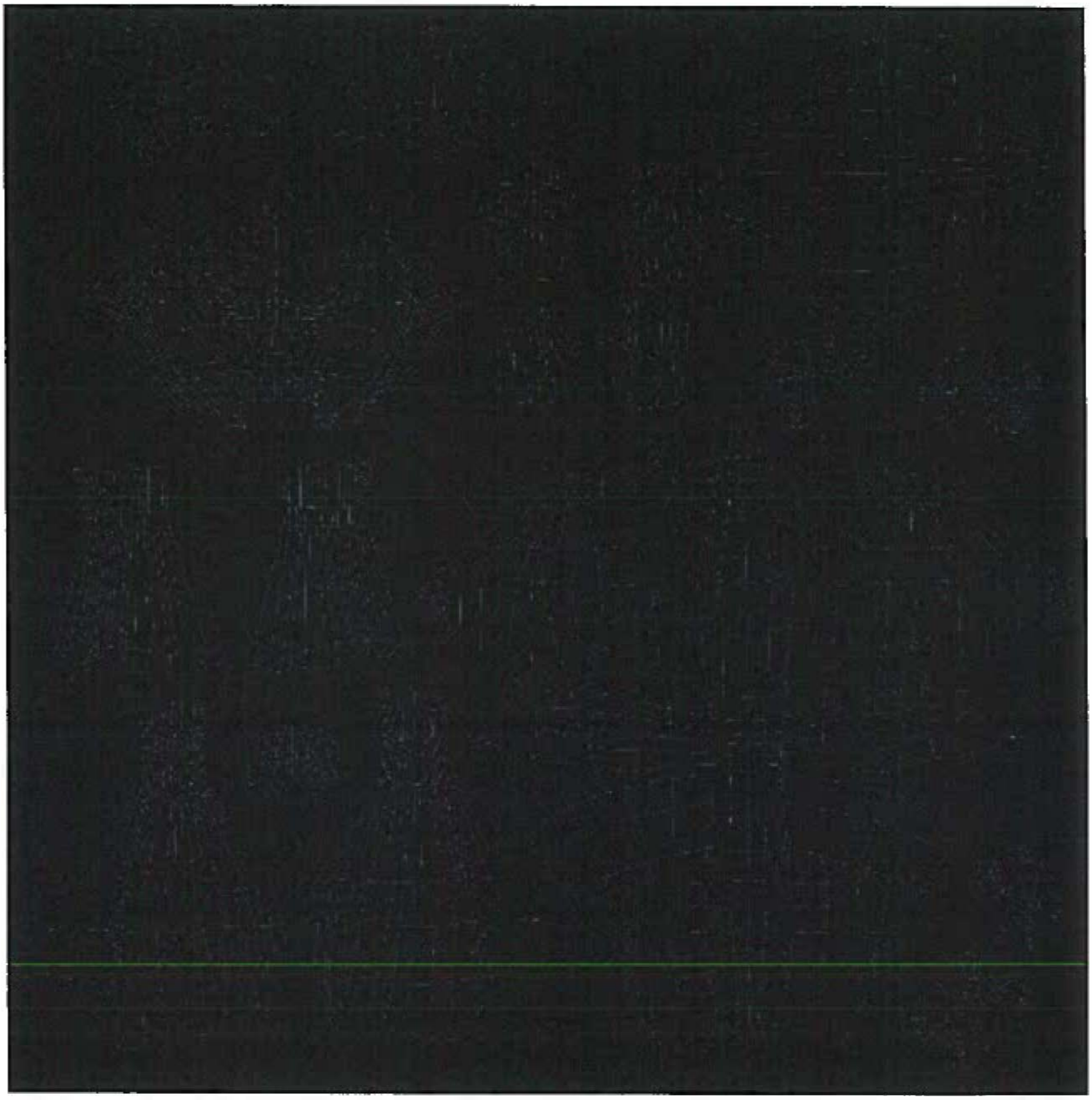


Figure 3. The unwrapped "UVW" template for the textures on the 3D fox model.

Rigging and Animation of the Model

In order for a model to be animated, it must be rigged (see figure 4 to view the final fox rig). This process involves placing *bones* in the 3D model. These bones are then constrained to control objects. The control objects are used in the animation process to manipulate the model to the desired movement. Once the bones and joints are placed inside the model, the next step is to "skin" where the mesh is actually attached to the bones, which as previously mentioned, are then controlled by control objects, also called control curves. The closest real world example to a rig would be much like the strings of a marionette puppet.

The movement depicted in the rendered animations was created as realistically as possible. Orthographic videos of standard gaits of the domestic dog were referenced for accurately portraying locomotion of the red fox. Both being canines, domestic dogs and foxes are known to share the same quality of movement. Five gaits were selected to be animated; walk, pace, trot, canter, and gallop, each possessing successively more rapid beats, or steps. Each animation was created with a seperate copy of the 3D fox mesh. In order to view each animation, the associated mesh had to be toggled to be visible or hidden to the viewport within Maya.

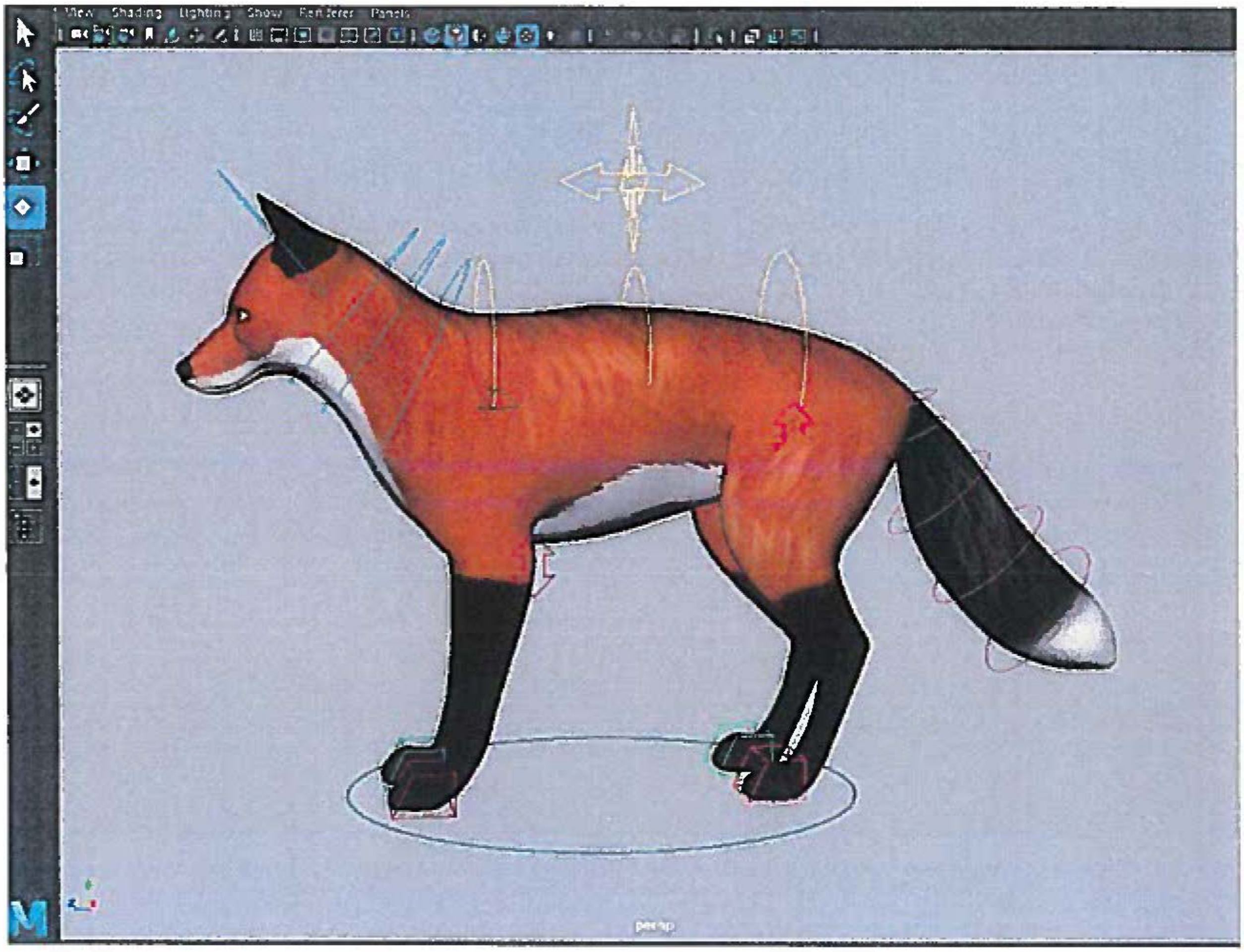


Figure 4. The completed rig and applied red fox texture. The control curves are the brightly colored circles, boxes and lines in the image that are used to manipulate the model.

Lighting, Rendering, and Composition

With the model finished, textures applied, and animation successfully completed, the final step within the software was to light and "render" individual frames of the animation in order to be exported (see figure 5 for an example of a still frame), and later "composited" into a more universal video format.

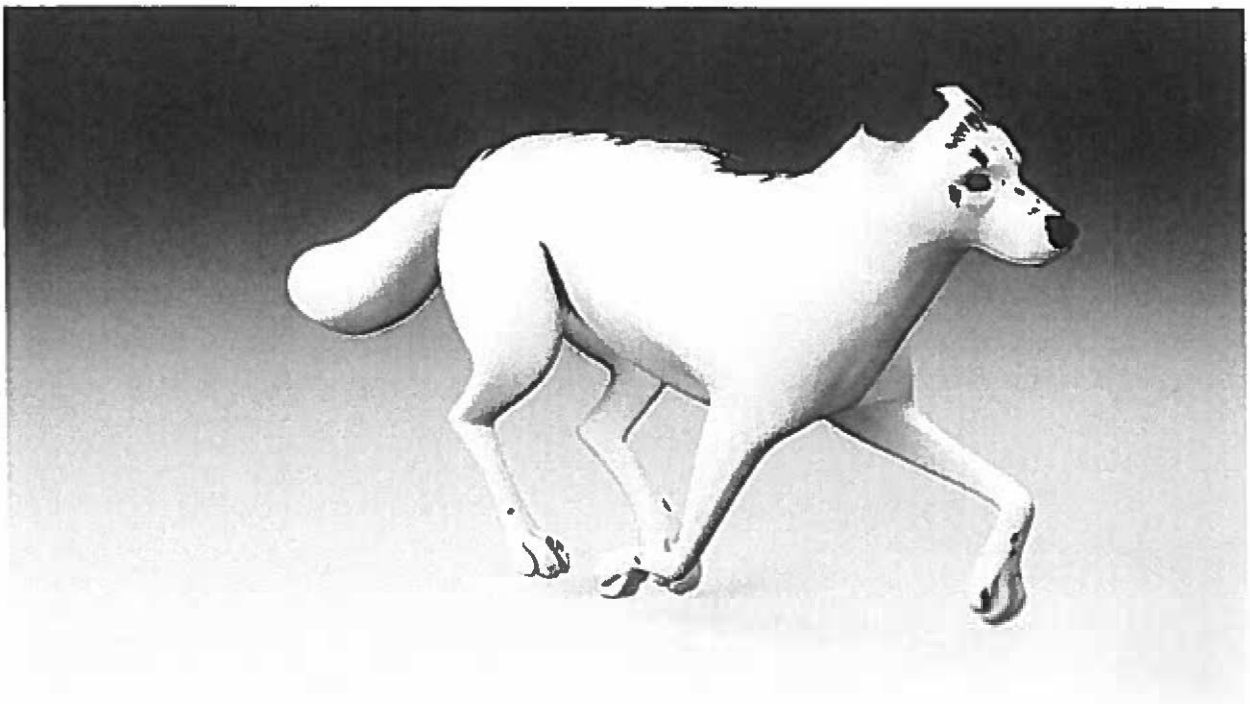


Figure 5. A final rendered still image from the canter animation cycle of the Georgian white texture of the red fox.

Maya supports several software plug-ins to light scenes in the 3D environment. Maya has its own native lighting systems, but a preferred industry standard system that was utilized was V-ray. V-ray was developed by the company, Chaos Group. V-ray, much like other lighting software, generates renders by using complex algorithms that calculate the behavior of light particles ("V-Ray for Maya - Professional Rendering Software for VFX Artists").

Setting up lighting in a scene follows the same real-world principles of setting up studio lighting. It required the creation of a key light, a fill light, and a rim light. The key light is placed at an angle in front of the model, and the intensity was adjusted to accommodate the color of the model. Setting the intensity of the light too high resulted in an overexposed and blown out look, while light too dark will not allow details of the model to be properly seen. The fill light then reduces the contrast, and the rim light helps define the outline of the model.

Once the lighting is satisfactory, the rendering process begins. While the lights are being set up, single frames are rendered to test the lights, but then the entire animation cycle must be rendered after. Because rendering entails the calculation of light particles, or photons, the render can take several minutes to be generated.

With twelve colorations, each having been animated with five different animation cycles, and each animation cycle having between twelve and thirty frames, the total frames rendered was approximately 1,200. Each frame averaged at least a minute to render, translating to roughly 20 hours total render time. Whenever possible, rendering was divided between multiple computers, allowing frames to be rendered simultaneously, instead of allowing all the frames to monopolize one computer for nearly a day.

Once each and every individual frame was rendered, they could be composited. Composition refers to the process in which the frames are placed in a video editing application, and played back at a speed of 24 frames per second, in order to create the appearance of motion. The application used was Adobe After Effects, another industry standard software application. The final application in the video rendering process is Adobe Media Encoder, which, as the name implies, encodes the media, or formats a video file output that is able to be read by the majority of video playback applications.

Finally, there were sixty video clips total, which could now be assembled for proper viewing.

Assembling the Project

Ultimately, the decision was made to present the video clips, text, and audio in a PowerPoint presentation using built-in action buttons. Action buttons allow a viewer to click links to slides within a presentation.

The first slide of the presentation is an index of all the information presented in the PowerPoint; the introduction stating the rationale behind its creation, links to each of the colorations, a link to view a glossary of terms in the presentation, a quick how-to guide to navigate the presentation, credits, and a button to begin the presentation (see figure 6).

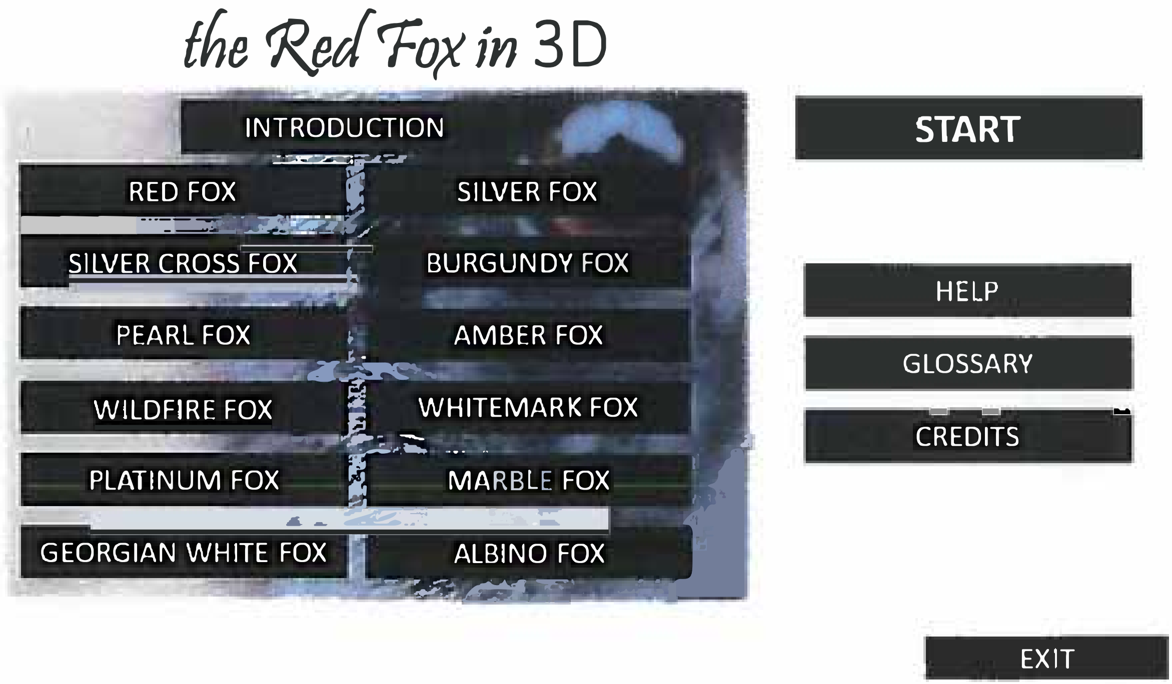


Figure 6. The first slide in the PowerPoint presentation.

Using a simple linking process, the presentation was set up so that a user could click through using black arrows in the upper right hand corner. As a viewer clicks through, they will be greeted with each red fox color. Opening the slide will cause the walk cycle to play, and then the viewer can click buttons that will allow them to view the pace, trot, canter and gallop cycles on separate slides as well. Accompanying the video clips is corresponding information about the coloration. Text in the slide details the genetic background of the fox color mutation, information about when the coloration was first documented, a written description of the fox's appearance, and any other relevant details about the coloration (see figure 7).

Above the text displayed, is a button to play an audio narration of the text below. This narration was recorded in Audacity, exported as a .WAV file, then imported into PowerPoint.

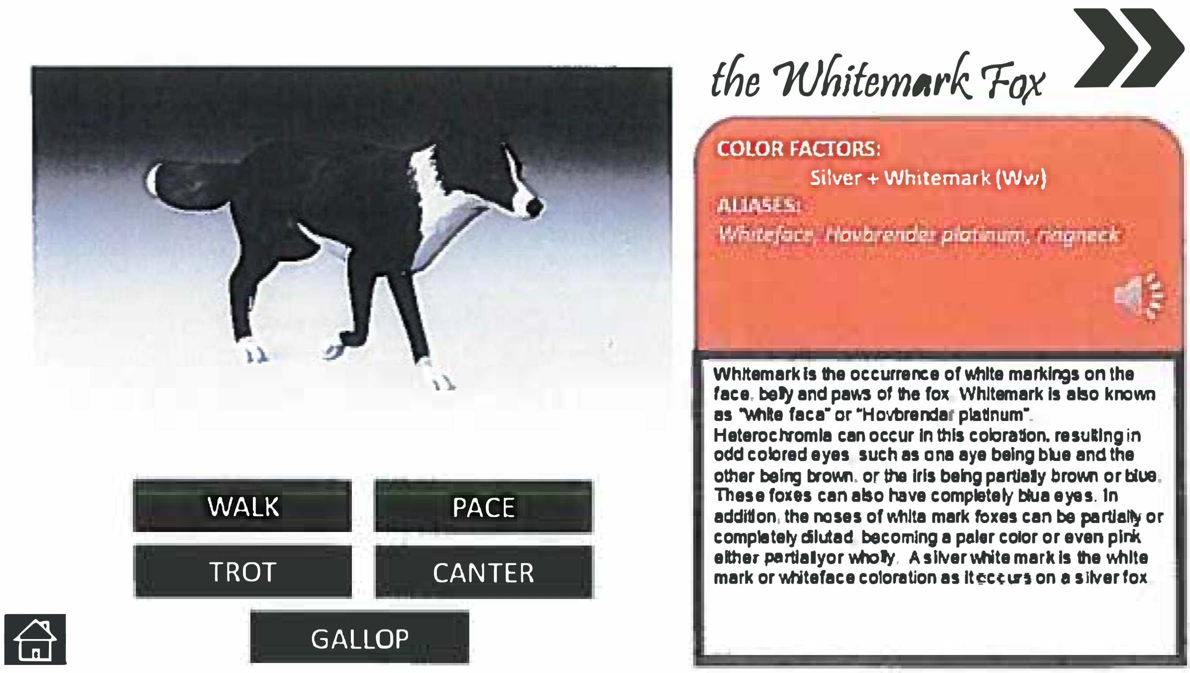


Figure 7. The slide within the presentation displaying the animation of the whitemark fox, trotting, alongside relevant text and audio information.

In total, there were 60 slides for all the fox colorations. Once the PowerPoint was finished, it was finally time to present all the research, 3D art, and information to my SAG 485 Senior Capstone classmates.

LESSONS LEARNED

My greatest area of growth throughout this project has been in the realm of 3D. I have learned how to create 3D models through Autodesk programs such as 3ds Max and Maya. I have come a long way from creating primitive objects to developing complex, visually pleasing hard surface models as well as organic creations. I am still actively learning about elements of good 3D models, such as clean topology and the use of concepts such as holding lines. I actively seek out feedback on my 3D models and have received a great deal of praise for my understanding of concepts that contribute to quality 3D assets.

As will be explored later, I originally began this project with the intention to graduate in April 2017. However, due to multiple setbacks, I had to delay my graduation a year, after failing my senior thesis course. Though I wanted to repeat the project, I was not permitted to reuse any previously created assets. In 2017, I created a fox model in 3ds Max, which was one of my first major attempts at creating a full-body, organic model. I recreated the model again in 2018, this time in Maya, and the improvement was obvious. I was able to include more details, especially in the face and paws of the red fox. My model created in 2017 (figure 8) and model created in 2018 (figure 9) provide a direct visual of my improvement as a 3D artist.

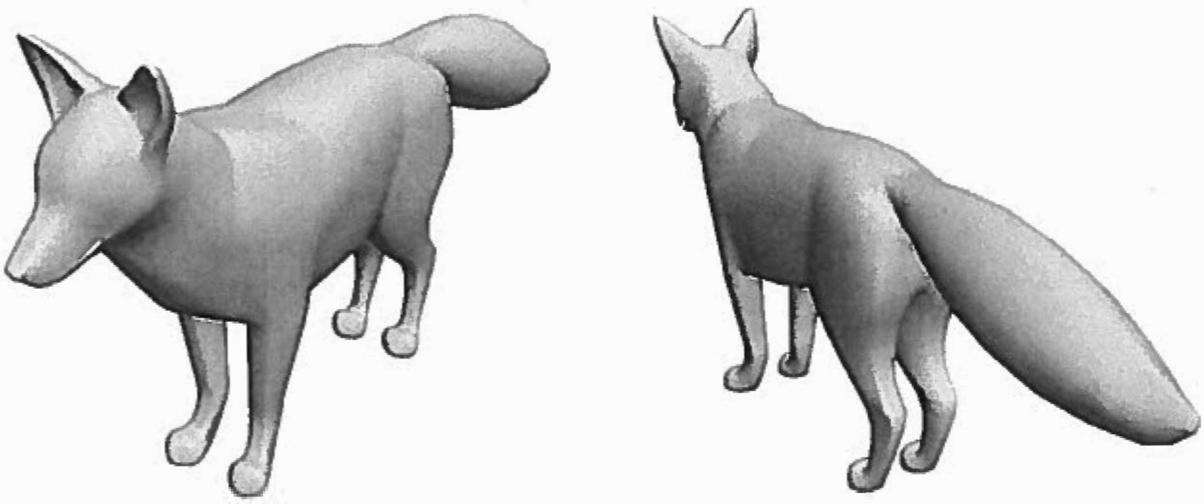


Figure 8. The first fox model created in 2017 in the Autodesk program, 3ds Max.

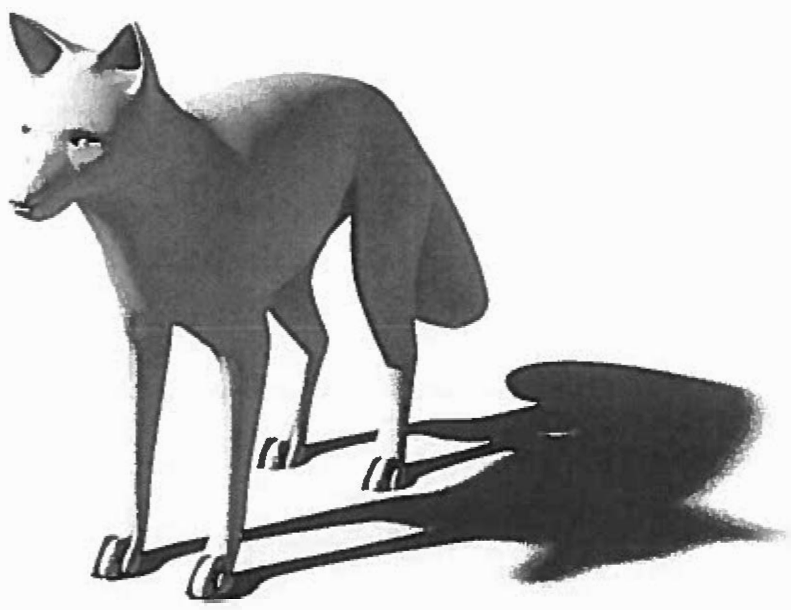


Figure 9. The final red fox model created in Autodesk Maya that was used in my final senior thesis project.

Texturing, as opposed to the difficulties of modeling and rigging, came much more naturally to me. I greatly enjoy unwrapping the UVW coordinates of a model, painting and working in a digital art program to render the texture, and creating outstanding textures. Once the texture is "unwrapped", texturing can continue along smoothly. Having a great deal of experience in the digital painting and illustration realm, this was a relatively painless step. I do wish I could have had more time to work on the textures, as I would have greatly enjoyed adding more details, and exploring other, more realistically and eye pleasing ways to depict the fox's fur. But, it was important that I move onto more challenging aspects of the project.

Rigging was the greatest challenge for me, but it was through close guidance with my professors and peers that I was able to grasp the fundamentals of rigging. Rigging was a process I learned over the course of my last couple of years at Eastern Michigan University, and is a reoccurring skillset as one moves through the higher level courses offered by the Simulation, Animation and Gaming Program.

Originally, I learned the rigging process in 3ds Max, and some of those lessons transferred to Maya. However, there were different ways of creating relationships between the bones, joints, mesh and control objects that differed from each program. Though similar principles were intact, I had to grapple with a new software package during my senior semester.

While working on my senior project, I recreated the rig several times with several different approaches. Each time, I often gutted or completely restarted the rig due to issues specific to the rig. This issues included the joints in the rig "popping", a bone failing to follow the correct skeletal hierarchy, and other complex issues that are difficult to troubleshoot.

The relief in finally completing a rig was immeasurable, but it was not the end of my difficulty. After the skeleton is in place, the mesh must be skinned, as mentioned previously in this thesis. As intelligent as the software is that handles these operations, there are limits to what the program can do, and what must be manually finessed by the artist.

When skinning the rig, the bones will "grab" the nearest geometry on the mesh. This is not always what is desired - for example, a leg bone may pull vertices located on the stomach, when this is very much not appropriate when animating the creature. To create a proper relationship, I had to go through the weight-painting process, where I very literally paint on the mesh. This is how I "tell" the joints where to grab the mesh, and how little or how much to do so.

Despite going through the tedium of weight painting, there was still some unwanted warping in the mesh during the final animation process. This was one of many points where I had to accept that this was the extent of my ability in my timeframe, and let go of perfectionism. I curtailed the wrapping to a minimum.

When it came to animation, the satisfaction of overcoming previous challenges became realized. To see my modeled, textured, and rigged red fox in motion was incredibly rewarding. Animating was largely a breeze, and was easily one of the most enjoyable aspects of this project. The issue of the mesh warping was still present, but I carefully tinkered with the movement of the control curves to minimize the appearance of this problem.

At long last, the final process was to render, composite and input the videos into the presentation, a process already detailed above. This was not particularly difficult, only time consuming and having a great deal of tedium, but at the end of the tedium, was a completed project.

Personal Reflection and Academic Growth

Since I was very young, I have been passionate about animals and representing animals in art. I have had a very keen interest in foxes and their domestication for years, insofar that I even had a pet fox for three years before surrendering her to an exotic rescue due to unforeseen life circumstances. I have remained heavily involved in the social media scene of pet foxes, and have become personal friends with many pet fox owners, breeders, and even fur farm ranchers. I have read countless amounts of literature relating to the red fox in captivity and in the wild, and therefore, I eagerly embarked on this project.

The personal impact of this project cannot be understated. As mentioned before, this project was originally attempted in what was my originally anticipated graduation year, 2017, before my graduation was delayed, and the project restarted.

This did not have to do with my own willfulness, wonton, or lack of volition, but instead was a result of a great deal of personal strife and struggle. In March 2016, I was first hospitalized and then again hospitalized for the same reason in November of 2016. The reverberations of these events still echo into today, setting my graduation back, and resulting in a complete restructure of how I envisioned my senior year. It also challenged my notions of what made me a good student, 3D artist, and person. It forced me to understand that great feats cannot be done alone. I especially received a great deal of help from my friends and family, but also my faculty mentor, Jeremy Catarino. His patience, guidance, and pushing played an integral factor in my success and the completion of this project. The Honors College also served as a pillar of support for this project. During her time at the honors college, Rebecca Sipe, Honors College director, was an immense source of reassurance and understanding. Her warmth and kindness was beyond compare, the times I was able to step into her office and tell her what was going on in my life.

This project stepped outside the bounds of a classroom experience, becoming a unique blend of my artistic abilities, technical skills, research interests, and academic excellence. It also tested my own personal willpower and perseverance in the face of near hopelessness, at times.

My original goal was to create bridges between several circles and disciplines. Namely, I sought to lend validity to the use of 3D computer applications and imagery as learning devices. I also, through this project's process, and during my tenure at Eastern Michigan University, have become a representative of the university, the College of Technology, the School of Visual and Built Environments, the Simulation, Animation and Gaming program, and the Honors College. I have also proven to myself the power of my own ambition, as well as the heights I can reach with the supports of all the aforementioned academic circles.

I have come to understand the academic process that entails creating a thesis; a critical component of graduate studies and research beyond. I learned to work under the demands of a stringent timeline. This project now operates as a portfolio piece to future schools and employers to my ability to plan, collaborate, research and execute ideas and concepts.

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