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Tooth Farmer: Exploring 3D Printed Replacement Heads for Stop-Motion Animated Films

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TOOTH FARMER: EXPLORING 3D PRINTED REPLACEMENT HEADS FOR STOP-MOTION ANIMATED FILMS

By

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ABSTRACT

Tooth Farmer is a 2-minute hybrid animated short film combining stop-motion puppetry with a 3D environment. *Tooth Farmer* is a vital story as it was developed over four years and getting closer to the artist's goal of creating a successful stop-motion armature puppet that is durable for an entire stop-motion short. The story is a different take on the Tooth Fairy mythology that varies from culture to culture. This story offers an alternative to the world of the Tooth Fairy folklore. In *Tooth Farmer*, a little mouse lives inside a person's mouth to help maintain tooth hygiene. The film focuses on unique character designs with environmental concepts resembling a person's mouth. Armatures from the company LAIKA and Aardman Studios heavily inspired the explorations of stop-motion puppetry. Using the Elegoo Mars Pro 2 and Standard Photopolymer Resin to create 3D printed heads with 23 facial expressions for the main character was a huge goal and purpose for creating this animated short film. Delving deep into research for building a physical armature for a stop-motion puppet and compositing a 3D render scene was a challenge with harmonizing the design of physical objects with digital scenes. The paper documents the processes used in creating a hybrid film. It explains what the artist did, what the artist should have done, and what the artist can improve in the future.

YouTube Link for *Tooth Farmer*: https://youtu.be/ky2HE4SkaDo

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INTRODUCTION

Tooth Farmer is a story of a little anthropomorphic mouse who takes care of the inside of a child's mouth, intending to help the child outgrow their baby teeth. This short parable draws influences from a French fairytale, *La Bonne Petite Souris* (d'Aulnoy). Tooth Farmer integrates a stop-motion puppet with 3D-rendered environment scenes.

Tooth Farmer has one character: the farmer. The farmer is a dental hygienist in the form of a tiny mouse who cares for the inside of a boy's mouth. The decision to have a rodent as the main character is due to the cultural history of what is deemed as a tooth fairy. Like the French fairytale *La Bonne Petite Souris*, much of the world has always used the imagery of a mouse as a 'tooth deity'. Rodents' teeth continually grow during their entire life. Early Norse and European history suggest that a baby tooth was buried to spare the child from hardship in the next life. Early Vikings were documented as carrying their children's teeth to bring them good luck when fighting in battles. Teeth have a long history of being a memorable symbol as each person grows into the following stage of life (A Brief History Of The Tooth Fairy).

The story begins with the farmer cleaning the giant mountain-sized teeth next to the farmer's home. As the farmer cleans the person's teeth, an earthquake erupts with giant rocks falling from the sky. When the rumbling stops, the farmer assesses the destruction left behind. A giant piece of candy is stuck between two teeth that tilts forward and threatens to crush the farmer's home. Watch as we follow the farmer who decides how to clean the candy without it falling on his house.

CHAPTER ONE: WHY

Stop-motion films have inspired filmmakers and animators for over a century, offering a unique visual style and narrative possibilities. Stop-motion uses a technique that takes physical objects and captures the subject one frame at a time with a camera. This technique has led to some of cinema's most iconic and memorable films. Starting from earlier works such as *The Cameraman's Revenge (1912)* and *The Adventures of Prince Achmed (1926)* to contemporary masterpieces like *Coraline (2009)* and *Isle of Dogs (2018)*, stop-motion continues to be a source of creativity and innovation that has evolved. Its timeless appeal lies in its organic quality, the ability to bring inanimate objects to life, and tell imaginative stories that captivate audiences of all ages. A particular mystery and magic comes about when watching stop-motion films.

The Adventures of Prince Achmed (1926) is a silent animated film directed by the German animator Lotte Reiniger and is considered one of the earliest animated feature films. The film is based on *The Thousand and One Nights (1704)* tale and features hand-cut silhouettes animated against hand-painted backgrounds. It is noted for its imaginative visuals and intricate animation and has been praised as a landmark in animation history. Despite its age, *The Adventures of Prince Achmed (1926)* remains a captivating and visually stunning film that continues to be enjoyed by audiences of all ages.

The astonishing fact is that items used in a stop-motion film are typically not supposed to move, such as Lotte Reiniger's paper cut-out puppets, but have the flexibility and personality of a character like a natural person in a live film.

Lotte Reiniger's characters and environment resemble traditional Asian shadow puppets using delicate cut-out silhouettes (Cavalier). Jamie Lachnicht tried this method of stop-motion paper cut-outs previously at the beginning of their stop-motion experimental phase. The complexity of using paper puppets was that the paper needed to be flat on the ground with minimal interruptions from surrounding movement. Another issue with using a paper cut-out puppet is considering the intent to use thick paper to paint textures, as wet paper tends to curl at the edges. Lotte Reiniger focused more on silhouette paper cut-outs of solid colors like black and white, so she did not have to worry about how the paint would affect the paper. For *Tooth Farmer*, the focus was solely on getting a 3-dimensional puppet flexible armature which has been seen in many stop-motion films such as *Rudolph the Red-Nosed Reindeer* or *Wallace and Gromit*.

In the 1964 Christmas stop-motion film *Rudolph the Red-Nosed Reindeer*, Rick Goldschmidt claims, "Even though the animation got more fluid as time went on, and it got more perfected, and things looked technically better, they still thought Rudolph was the best" (Delgado). The stop-motion animation was led by Ted Mochinaga, who worked with Rankin/Bass to create 23 beautiful sets for the film. The dedication from work put into the script, the environments, and the characters made for *Rudolf the Red-Nose Reindeer* made its mark as a critically acclaimed and iconic Christmas film that gets played yearly around the holidays. Even though it is an older film, the technique style is still used today with updated technology, such as Rapid Prototyping from companies such as LAIKA.

Aardman Studios adapted an Oscar-winning 30-minute film called *The Wrong Trousers*, featuring loveable characters *Wallace and Gromit* (History of Aardman). Aardman Studio mainly uses claymation for their films, which is another technique found in stop-motion. Claymation is warping clay or Play-Doh while taking individual camera shots to create a cohesive illusion of movement when combining the sequence. In Aardman Studios, *Early Man*, 2018, they shifted from claymation to 3D-printed models. Even though they used a 3D printer in an earlier film of *The Pirates! Band of Misfits*, 2012, Aardman Studios ensured that their 3D models were similar to claymation, including fingerprints and uneven surfaces on each character's feature in *Early Man*. films. Aardman Studios was essentially avoiding such technologies because of the perception of the audience's reaction to keeping traditional stop-motion techniques that showed for a charming aesthetic (Silver). The stop-motion animation industry did not use 3D printers until LAIKA created its first film in 2009 called *Coraline.* The movie, *Coraline*, used LAIKA's Rapid Prototyping for the mass production of facial rigs by Brian McLean and Martin Maurier (Scott).

The primary purpose of *Tooth Farmer* is to replicate production using new technologies such as the 3D printer and explore new ways that improve stop-motion films. As for the story of *Tooth Farmer*, the premise revolves around an original storyline heavily inspired by Tooth Fairy lore and the culture of its origin. The story has gone through several revisions as it was initially conceived while waiting for a dentist appointment for an annual cleaning with the hygienist. The early concepts for *Tooth Farmer* were very dark and particularly uncomfortable for viewers, as most people would feel at the cold dentist's office. After much thought and discussion with a hygienist, the story's premise changed to a whimsical fantasy that would educate people to take

care when cleaning their teeth. There were many discussions about how most films that include the dentist are always scary and chilling tales. An example would be in 2003's *Finding Nemo* when Nemo is placed into a fish tank inside a dentist's office with all the scary tools and children around (Stanton).

Teeth are frequently seen throughout the film and are an essential motif and emblem in *Tooth Farmer*; in the background, there are massive teeth mountains or miniature teeth plants growing all through the farmland. The abundance of teeth makes the viewer understand that the agricultural environment is predominantly in a human's mouth. During the short film, Tooth Farmer, the main character, contends with food that is stuck between the front teeth and threatening to crush the character's home. Although the film is not entirely educational, there needed to be a fun story that subconsciously makes a viewer think about flossing and cleaning their teeth. While making the Tooth Farmer film, creating an environment resembling the inside of a human's mouth while not purposely grossing someone out was challenging. To help create an entertaining environment, a vibrant color scheme was used.

As for the color schemes in the background, *Tooth Farmer* had to show a colorful and quirky style that aligned with the storyline. Since the environment is solely located in the mouth and on a human tongue, pink is in most of the film for the leaves, grass, and ground plane. The intent was to avoid the typical greenery colors such as green and brown; the environment had to match the location where a healthy mouth is vibrantly pink. Intentionally, the environment had to avoid green and brown when contrasting with pink as the main color scheme. As for the main

character in *Tooth Farmer*, the mouse is connected to the environment by choosing a similar but distinct shade of pink to associate both entities as one cohesive idea.

Continuing into the decision for materials to create the stop-motion puppet armature, there were many decisions, failures, and iterations before completing the final puppet. The most challenging obstacle for *Tooth Farmer* was building a resilient and flexible stop-motion puppet that could be used for an entire 2-minute animated film of 3,911 frames of animation. In future chapters, this paper will explain the decision to use silicone mold-making puppets with the use of 3D-printed replacement faces. The most significant hurdle was making the puppet's body and researching how Rapid Prototyping could be helpful, from software like Pixologic ZBrush to the 3D printer.

3D Integration

Stylistic choices are an essential aspect of storytelling and can significantly enhance the narrative, especially when deciding the style for *Tooth Farmer*. The stop-motion puppetry had to integrate seamlessly with a 3D-rendered background, which requires much consideration for the finalized puppet. LAIKA had an example of their production pipeline process from their film *Missing Link* (2019).

In a video found on YouTube called *Realizing the Potential for Stop-Motion Animation with LAIKA VFX Team*, quick visuals of side-by-side shots of how LAIKA combined their stop-motion puppets and scenes with the 3D modeled assets. The renders of their movies come out seamlessly, and the style is wholly handled which ensures the viewer cannot tell what is hand-

made or computer generated. LAIKA released small snippet videos on the production pipeline that shows the raw 3D model, texture, render, lighting, FX, and composite. Even though the YouTube video was short, it revealed LAIKA's production pipeline process. It was a helpful resource when adapting to *Tooth Farmer's* pipeline production (Knight, Realizing the Potential for Stop Motion Animation with LAIKA's VFX Team).

Tooth Farmer's environment had several iterations in the design and layout, with much consideration for placing the candy crumb stuck in between the two front teeth. The final layout was finalized with a green and yellow house under the candy crumb towards the front of the mouth to help break up the intense pink colors in the environment. Shown below are example images of the *Tooth Farmer's* environment.

Figure 1: Tooth Farmer Rendered Layout

CHAPTER TWO: EXPERIMENTING WITH PUPPETRY ARMATURES

Materials Used

The software required for *Tooth Farmer* was DragonFrame, Foundry Nuke, Autodesk Maya, Adobe After Effects, and Pixologic ZBrush. The 3D Printer that was used is the Elegoo Mars 2 Pro with Standard Photopolymer Resin. Other materials used to create *Tooth Farmer's* puppet armature were Sculpey Clay, Silicone Molds, Aluminum Wires, and Needle Felting.

Creating a Flexible Armature for Stop-Motion Puppet

Stop-motion armatures are a crucial component in the process of creating stop-motion animation. It serves as the internal skeleton of the puppet and provides support and flexibility for movement. The armature is typically made of lightweight materials, such as aluminum wire, brass tubing, or ball-and-socket joints, designed to be easily manipulated by an animator. During the creation of Tooth Farmer's armature puppet, these materials were used from experimenting through trial and error.

Armatures can be constructed based on the specific needs of the puppet and the desired movement. Ball-and-socket armatures are the most common type and consist of ball joints that provide a wide range of motion and flexibility. Wire armatures are more straightforward and typically used for puppets that do not require complex movements. Silicone armatures are another option that provides more realistic movement and fluidity in the puppet.

For *Tooth Farmer*, the experimentation of the ball-and-socket armature was tried twice, with both being failures. The first trial was hand-drilling aluminum blocks, which were so hard that the drill bit would break numerous times, and the process took several weeks as it was very labor intensive. The second trial combined ball-and-socket armature with a layer of silicone using Mold Star 30 and Dragon Skin Mold Star 10. The use of rubber silicone was vastly expensive and because of that, experimenting with the drying process was not cost effective. The process of casting a mold would have been successful with a few more trial executions, but there was little time allotted after many failures.

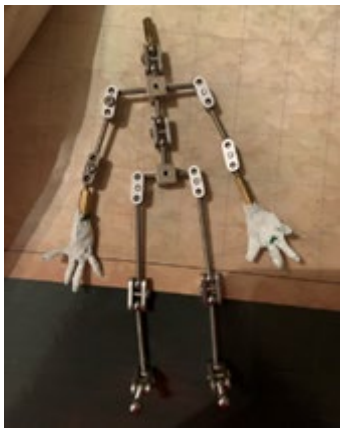

Figure 2: Ball-And-Socket Armature 2nd Trial

Figure 3: Mold Star 30 Layered On Armature

The cast of the mold was a success until the Dragon Skin Mold Star 10 was placed inside the cast without the realization of placing the lubricant on before pouring. Silicone sticks exceptionally well to itself, whether wet or completely dry unless lubricant is placed over the layer of dried silicone. That step was skipped while panicking that Dragon Skin Mold Star 10 was drying within a few minutes while mixing Part A and Part B.

Figure 4: Failed Dragon Skin Mold Star 10

With a whole pint bottle left of Mold Star, it was re-casted on a pair of hands to reduce the amount of silicone used. Besides acknowledging how fast Dragon Skin Mold Star 10 takes to cure, the step-by-step process was identical. The hand cast was by far the closest success for the silicone mold process, with the only issue being air bubbles trapped in some of the layers of the silicone.

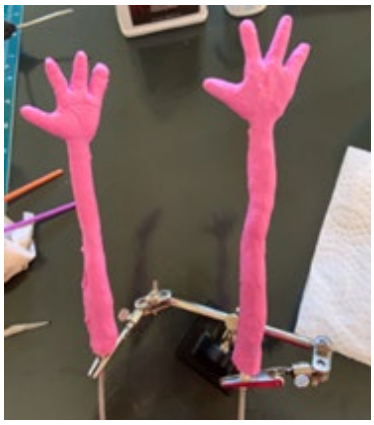

Figure 5: Silicone Hands Cast with Air Bubbles

The construction of a stop-motion armature requires knowledge of materials and fabrication techniques and an understanding of the principles of movement and animation. Typically, the armature is constructed first, and then the puppet's exterior is applied, which includes foam, silicone, aluminum wires, yarn, and needle felt. After completing the Mold Star silicone arms for *Tooth Farmer*, the next step was to build the body of the armature using foam, sew the character's outfit and needle-felt the arms to add textured fur to closely resemble a mouse.

Figure 6: Tooth Farmer's Completed Armature

In conclusion, a stop-motion armature is critical to creating stop-motion animation. Its construction is tailored to the needs of the specific puppet and desired movement. With suitable materials and fabrication techniques, stop-motion animators can create armatures that provide the flexibility and support necessary for a successful animation.

CHAPTER THREE: RAPID PROTOTYPING

Stop Motion Filmmaking: The Complete Guide to Fabrication and Animation is a book by Christopher Walsh and a valuable resource with many helpful tips on building a stop-motion puppet physically or digitally. The book goes into depth about how to approach facial replacements by giving step-by-step instructions. Walsh explains how to map out needed facial expressions for a character and how the mouthpiece will fit into the puppet's internal head for the replacement pieces to be swapped out flawlessly between facial expressions. The steps begin in Autodesk Maya and transfer the 3D model into Pixologic ZBrush to easily add blendshapes that warp the facial expressions to the desired look (Walsh). Christopher Walsh's book was the stepping stone into rapid prototyping.

Tooth Farmer had gone through many failures before successes in experimentation during the production pipeline. Bouncing between different programs online and deciding the most plausible option to composite a physical puppet into the 3D-rendered environment was a huge hurdle to overcome.

The first hurdle was exploring ZBrush sculpts to fit the aesthetic of the physical armature body for the farmer. Pixologic ZBrush is a popular digital sculpting and painting software that can create 3D models and 3D renders. While ZBrush is primarily used for sculpting and texturing, it also has some capabilities before 3D printing, such as applying the plugins of DynaMesh and Decimate, which helps simplify the model before sending it to the printer. Utilizing these ZBrush plugins helps administer clean-up to lessen the polygon count while sustaining the details in the sculpted model.

Figure 7: Jamie Lachnicht's Final ZBrush Head Model

After completing 3D sculpting, Dynameshing, and Decimating, the final step is exporting as an STL file. An STL file is a standard 3D printing and CAD software format. STL stands for "stereolithography", a type of 3D printing technology. STL file types are popular for 3D printing because they can easily be sliced into thin layers when imported into softwares such as CHITUBOX. The CHITUBOX software is a slicing and editing tool that can create pillars to support a 3D model during the resin printing process and preps the model with the correct measurements to fit the printer plate of the Elegoo Mars 2 Pro. The process used to create a successful 3D print pipeline was from the 3D Character Workshop by Shane Olson (Olson).

Shane Olson is a well-known 3D artist who has worked on several popular films and video games with companies like Disney Interactive. He offers online workshops and courses on character creation in ZBrush. The 3D Character Workshop with Shane Olson is a comprehensive course covering the entire process of creating a 3D character and bringing the ZBrush file ready for 3D printing.

Another inspiration for *Tooth Farmer's* 3D printed head was from LAIKA. This stop-motion animation studio is known for its innovative and visually stunning films, including

Coraline, *Paranorman*, *The Boxtrolls*, *Kubo and the Two Strings*, and *Missing Link*. LAIKA has been praised for its meticulous attention to detail, sophisticated storytelling, and groundbreaking use of 3D technology in stop-motion animation. *The Art and Science of LAIKA* is an interview on YouTube between Brian McLean (Director of Rapid Prototyping for LAIKA) and Steven Emerson (VFX Supervisor for LAIKA). The conversation concerns how the studios combine stop-motion animation, cutting-edge 3D printer technology, and computer-generated imagery (CGI). Brian McLean has been an integral part of LAIKA's success, bringing his expertise in 3D printing and rapid prototyping to help the studio push the boundaries of stop-motion animation (Emerson).

One of Brian McLean and Steven Emerson's most notable contributions to LAIKA's animation process is 3D printing to create replacement faces for the studio's stop-motion puppets. Traditionally, stop-motion animators would have to manually sculpt and mold each facial expression for their characters, a time-consuming and labor-intensive process. McLean and Emerson's 3D printing allows for faster and more accurate creation of replacement faces, giving animators greater control over the character's expression and emotions. They have used their digital modeling, animating, and rapid prototyping expertise to enhance and streamline the animation process.

During the interview of *The Art and Science of LAIKA*, McLean and Emerson discussed that the creation of Kubo's single head took up to 12 hours to print from *Kubo and the Two Strings*. LAIKA had a long partnership with Stratasys and Cuttlefish to use a Beta of the newest Stratasys J750 printer, the company's first full-color, multi-material 3D printer. This printer had 360,000 different color combinations, which reduced LAIKA's production pipeline and

innovated the process. Every movie created by LAIKA Studios, has required the production of more printed faces for their characters. *Coraline* had 20,000 faces, while *Kubo and the Two Strings* had 64,000 faces (The New Faces of LAIKA).

Figure 8: Jamie Lachnicht's Ready-To-Print Replacement Head

Figure 9: Jamie Lachnicht's Ready-To-Print Side View

LAIKA's use of 3D printing to create replacement faces for their stop-motion puppets has revolutionized the art of animation, allowing for greater precision and control in creating facial expressions and emotions. Considering that *Tooth Farmer* is a stop-motion film, the experimentation of 3D printing replacement faces was a significant priority for the armature puppet. The University of Central Florida provided the Elegoo Mars 2 Pro, a resin-based 3D

printer designed for printing in enclosed spaces. One of the main features of the Elegoo Mars 2 Pro is its monochrome LCD screen. Unlike traditional color LCD screens used in many other resin-based printers, the monochrome screen used in the Mars 2 Pro is faster and more durable, allowing for faster printing speeds and longer-lasting performance. The printer is compatible with various resins, including the one used in *Tooth Farmer*, Standard Photopolymer Resin.

The Elegoo Mars 2 Pro printer uses the CHITUBOX software to generate support structures for 3D prints. These structures are necessary for printing complex models and prevent the printed object from collapsing during the printing process. CHITUBOX allows users to customize the placement and density of support structures and automatically generate them based on the complexity of the model. It also includes a built-in slicer, which divides the model into layers and optimizes the printing process for various 3D printers (Chitubox).

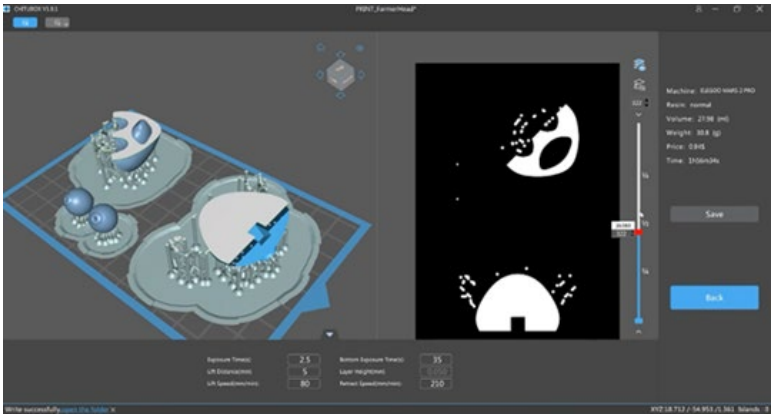

Figure 10: CHITUBOX Slicing Timeline

Every attribute of research and experimentation resulted in the final composition of *Tooth Farmer*. Several test prints failed before a successful print was created using the correct amount of density to the head and connecting matched keys to each facial feature with precise accuracy.

Figure 11: Jamie Lachnicht's Test Head Print with Keys

There were 26 expression pieces that were created in Pixologic ZBrush using Autodesk Maya blendshapes included in the software. Each expression was made with a new layer that was modified to the specific facial expression needed. The blendshapes were automatically created to be imported into Autodesk Maya. CHITUBOX can take in OBJ files directly exported from Pixologic ZBrush, so there was no reason to bring the file into Autodesk Maya. Once all expression files were exported and placed into CHITUBOX, each print file took approximately four hours for each piece to finish. Calculating the time it took for each piece to be printed was a total of 104 hours to print. While contending with time constraints, continuous print cycles were closely watched. Watching the prints constantly for possible failures was critical; each print took a total of ten days to complete all 26 expressions.

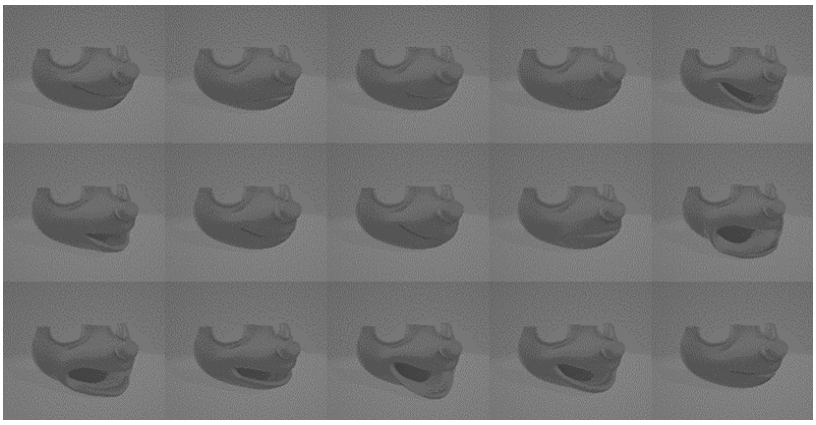

Figure 12: Jamie Lachnicht's Rapid Prototyping Mouth Pieces

Figure 13: Jamie Lachnicht's Painted Rapid Prototyping Heads

The images listed above total 26 replacement headpieces for the *Tooth Farmer*. The facial expressions range from happy, sad, and angry. The heads were painted with acrylic paint with a pink hue that color-matched the needle-felt fur on the *Tooth Farmer's* arms.

CHAPTER FOUR: CONCLUSION

Towards completion of *Tooth Farmer*, I learned from many of my own mistakes. Most of what I think of now are knowing what I can do differently next time from the failures that I've encountered. I accomplished what I sought to get done, such as experimenting with Rapid Prototyping and researching different techniques to create a stable stop-motion puppet armature using 3D printers.

Future plans for *Tooth Farmer* include entering film festivals and contacting local dentist offices to show the short animated film to children waiting for their dental appointment. My future exploration in the stop-motion genre will focus on perfecting 3D-printed replacement parts with the mobility and sturdiness that an armature puppet needs for an animation film.

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