Simulating and Designing Pyro FX to Communicate a Hostile and Magical Environment: An Honors Thesis Proposal

Brigham Young University

I. Purpose

A. The purpose of this thesis is to research, design, and create 3D fire effects to use in the context of the BYU Animation senior capstone film for the graduating class of 2025. I will be creating these fire effects with the Pyro FX tools in Houdini which allow me to both simulate and shade the fire to best fit the style of the film's environment. The goal is to make the film's effect look anime-like in pacing and shaping to match the action-adventure feel of the story. The film's story requires many different fire effects including torches, fire traps, and monster fire breath.

B. Based on the film's current storyboards, I need to simulate the torches igniting, flaring up, changing color, and moving with the characters. The fire needs to feel natural in motion and design but might be influenced by the magical events triggered by the film's protagonists.

C. The fire trap occurs at the introduction of the film's female protagonist. It needs to be explosive and threatening but also convey the spectacle of her skillfully avoiding the danger. Shaping and timing will be key for this effect.

D. The monster's fire breath also needs to be explosive and threatening. This effect will have more of an emphasis on the perilous, life-or-death situation the characters are in.

II. Importance

A. The work done on this thesis will be significant mostly just to the capstone film but will seek to imitate industry standard research and workflow. It will provide a good opportunity for me to deep-dive into pyro FX and achieve a high level of refinement for the fire in the film. Good fire effects look impressive and draw audiences into the story

that is being told. They help establish the mood and atmosphere of the story's environment.

III. Project Overview

A. Background and Past Research

1. Pyro simulations are broken down into voxels (3D pixels) that each contain values for the fire's density, temperature, burn, etc. at the specified location. These values have an impact on the shaping and movement of the simulation (SideFX, 2024).
2. Fire simulations are in high demand but tend to be difficult to animate due to their fluid and complex nature. Over the years, scientists have explored mathematically describing fire's behaviors using a number of equations, including the Navier-Stokes and two-dimensional Euler equations (Fedkiw et al., 2002; Nguyen et al., 2002; Nguyen et al., 2003). Most of these calculations are done under-the-hood when using the default Houdini solver.
3. Many effects require a solid understanding of the real-world physics to get an accurate art direction. Although this principle is still necessary to understand pyro effects, research has suggested that it is equally or perhaps more important to understand the pyro effect chemically to produce realistic results (Kearton, 2023).
4. Another good reference for art directing effects is *Elemental Magic: The Art of Special Effects in Animation* by Joseph Gillard (2009). The book covers the guidelines of classic hand-drawn animation and applies the concepts to designing special effects in the technological era of animation. Understanding the principles

of successful 2D animation is just as vital as the scientific background required to know how to art direct good fire effects.

5. I started out making fire simulations with the Axiom plugin in Houdini. Typically, pyro FX simulations run on the system's CPU, but the Axiom plugin allows for the simulations to run on the system's GPU with sparse calculations. Theoretically, this change results in faster renders (TheoryAccelerated, 2023). I was getting good results with Axiom, but then the film production switched Houdini versions, and now Axiom is no longer a viable option. I have plans to move forward with Houdini's default pyro solver and try to replicate my simulations with the tools it provides.

B. Future Research and Objectives

1. During the course of this project, I would like to further research the under-the-hood mathematical equations and variables that work together to create the fire simulations from Houdini's pyro toolkit. Even though I can use the Houdini pyro solver without a complete understanding of this math, it will help to dive deeper into the inner workings of the software so I can more effectively operate the interface.
2. I am also working on finalizing a torch Houdini Digital Asset (HDA) that will allow other FX artists to more effectively place torch fire into the necessary scenes. The final asset should have a variety of different torch shapes and simulations to choose from, along with the ability to change color, time scale, and other internal detail.

3. For the fire traps, I would like to experiment with adding additional particle and volume simulations which would add additional movement and influence to the motion. Shaping will be the most important part of making the effect feel spectacular and romantic, so I need to find ways to gain control over how the fire moves through the settings for buoyancy, turbulence, shredding, etc.
4. The monster fire breath will pull inspiration from fire-breathing dragons. It will likely be a similar setup to the fire traps, but I will need to experiment with ways to make it even more explosive and powerful.

IV. Committee

A. The Honors Coordinator for my major is Dr. Seth Holladay. He will also be my faculty advisor because he has considerable knowledge and experience on industry FX, shading, and lighting. He has a PhD in Computer Graphics/Computer Science and has worked as an FX artist at Pixar Animation Studios on many films, including *Wall-E, Up,* and *Ratatouille*. Currently, he teaches many of the animation classes here at BYU and does research in physical and fluid dynamics simulations for film. I have had him as a professor since the beginning of my computer science animation journey and have been impressed with the advice and encouragement he gives to his students.

B. Professor Craig Van Dyke will serve as one of my faculty readers. He also has industry experience working on visual effects at companies, such as Digital Domain, DreamWorks Animation, and Netflix. He currently serves as an executive producer for the BYU Center for Animation capstone films. I have worked with him since the senior capstone started last winter semester. During my time in his classes, I have seen Professor Van Dyke's

dedication to his students' growth and success and have learned a lot about what it means to be a professional FX artist in industry.

C. My second faculty reader will be Dr. Parris Egbert. He has masters and doctoral degrees in computer science and researches computer graphics and tools for computer animation. He is published in academic journals and conferences including Special Interest Group on Computer Graphics and Interactive Techniques (SIGGRAPH) and Computational Intelligence. I took his Interactive Graphics and Image Processing class here at BYU and enjoyed learning about computer graphics and how those concepts might apply to animation effects.

V. Timeline

	October				November				December					January				February				March					April			
	6	13	20	27	3	10	17	24	1	8	15	22	29	5	12	19	26	2	9	16	23	2	9	16	23	30	6	13	20	27
Torches																														
Convert to Pyro Solver																														
Finalize HDA																														
Shaders/Composition																														
Shotwork																														
Documentation & Breakdowns																														
Pyro Moving Source																														
Refining/Debugging																														
Doorway Fire Traps																														
Convert to Pyro Solver																														
Shaping for Robin's Intro																														
Shaders/Composition																														
Shotwork																														
Documentation & Breakdowns																														
Refining/Debugging																														
Monster Fire																														
Research and tests																														
Shaders/Composition																														
Shotwork																														
Documentation & Breakdowns																														
Refining/Debugging																														
Writing the thesis																														

VI. IRB Approval

A. This project will not require IRB Approval

VII. Funding

A. This project is fully supported by the CS and Design department resources.

VIII. Culminating Experience

A. The structure of this thesis will mimic the structure of a SIGGRAPH paper, and the resulting material will be professional shots and breakdowns that can be included on reels and in showcases. The hope is for the work done on this thesis to not only contribute to the senior capstone film, but to also contribute material to future presentations and submissions to film festivals and awards societies such as the Student Emmys or the Visual Effects Society (VES).

References

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