Creating Elemental Characters: From Sparks to Fire

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ABSTRACT

Pixar has a long history of creating high-quality effects and characters that aid in the telling of wonderful stories. With Disney and Pixar's *Elemental*, we have taken the next groundbreaking step in creating fully simulated, animated, and stylized characters. In this talk, we will present the framework and process that we use to create Fire characters.

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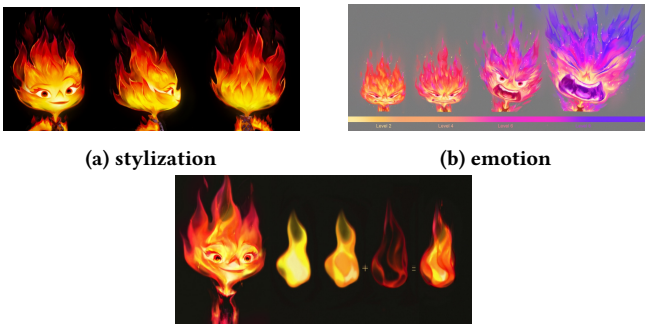
1 CHARACTER EFFECTS

Simulating highly dynamic and emotional characters 1 presents an enormous challenge for effects. Capturing subtle performance while maintaining stability without constraining animation requires rethinking the effects pipeline and finding new solutions to difficult problems.

We will discuss techniques for maintaining stable simulations, decoupling simulation dynamics from the visual flame, adding controllable internal details, and allowing animation to control the final results in an abstract way. These techniques are the basis for all fire characters in *Elemental*.

The most demanding technical challenge for tuning these fire characters is in the very nature of pyro simulations. The animation provides us specific shapes and performances to match the fire to, but pyro has the tendency to be one to three frames behind



(a) stylization (b) emotion

(c) flame layers

Figure 1: ***Reference Paintings*** ©Pixar

in evolving the sourcing to match the animation in a basic setup. Sometimes the animation can drive unappealing simulation results because it demands a frame by frame change as opposed to lingering and evolving. If a character drags their arm, for example, it's an expected movement to have in animation, but in volumes the result is large swathes of fire that can cover the performance.

Sourcing techniques to solve this included: removing or limiting linear transformations from the animation data using model pivots; preemptive distortion using velocity; interpolating frame change in sourcing instead of using substeps for exact control; additional layers of noise; clean-up using point clouds; all of this was target-specific using procedural, model-based masking.

The biggest advantage to solving this issue was the layered approach of the rig that decoupled dynamics from visual flame. The initial simulation generates the velocity field used for advection. The advection simulation generates the flame that will be seen in renders. This allows for flexibility in targeted changes to each field. Simulation techniques included: different noises generated inside, on the surface, around, and trailing the character; aggressive injection and pull values on sourcing; removing 95-99 percent of previous frame sourcing to achieve "replacing"; and actively killing volumes with zero velocity.

2 NEURAL STYLE TRANSFER

From the start, our artists would bring examples of illustrated fire and ask us to see the classic "cusps and curves" of flame animation represented in the silhouettes of our fire characters. Attempts to do so in pyro simulation often required a level of turbulence and scale that became visually distracting. Instead, we employed recent advances in Neural Style Transfer (NST) [Aurand et al. 2022] to transfer the features of illustrated fire onto our pyro post simulation. After many iterations, and a number of technical advances, we painted a set of style images that could imbue flame shapes onto otherwise smoothly gaseous simulations. This allowed simulation to focus on the low frequency movements, tear-offs, and general stability, while NST could help add shaping and style.

Our NST system used density and velocity as input and provided a displacement vector field as output. By modulating this field prior to application we could more carefully control NST's effect. We masked the vectors such that NST primarily reshaped the character silhouettes without creating any unwanted shapes in their core. Also, by modulating the input velocity, the speed with which the NST styles would move through the volume would change, which affected the perceived speed of the fire.

NST participated in the film's protagonist, Ember's, emotion system via rigged connections between the overall anger levels and several NST parameters. Increased anger would raise the tiling frequency of the style images, giving the impression of tighther and sharper flames. Increased anger would also blend between two different sets of target style images in order to bring out harsher details. Similarly, NST input velocities would be raised with increased anger, giving the fire a perceived speed boost.

3 SHADING

The shading of our fire characters presents a formidable visual and technical challenge as it needs to closely resemble real fire while maintaining an appealing animated look. The transfer of texture and paint into a fluid simulation and the advection of the painted elements in a naturalistic manner presents interesting challenges. Additionally, it is important to maintain the appeal of the facial features and overall character model, despite the unpredictable distortions caused by the simulation.

To achieve the right balance between realism and stylization, we used high-fidelity and high-resolution character volumes and added dynamic and continuous noise at rendertime. Our approach leverages signals from fire simulation to extract dynamic camera-facing volumes, preserving the movement and intensity of fire behavior while enhancing the 2D stylized drawing effect. We also invented a fire variation framework that combines various properties to map to different color ramps for character-specific fire coloring and volume density.

We have over 30 different fire characters, so we use a layered setup to customize each character's body shapes, colors, and movements based on emotional inputs from animation. This approach allows for adaptability and creative solutions while maintaining a shared processing framework.

Finally, we use a geometry-based weave system to address garment designs for fire characters. We map and deform chainmail segments at rendertime and apply character-specific patterns to create a rich set of garments specific to the culture of fire characters.

4 BACKGROUND CHARACTERS

Elemental boasts a variety of fire background characters, with 11 unique characters and up to four variations per character. To prevent monotonous fire behavior, a comprehensive rig was developed for the show. In some shots, background characters interacted with the features, requiring adaptable rigs that could maintain the highest quality. To convey each character's unique personality, simulation settings, models, garments, and shading were varied. Retrofitting Ember's rig to different models presented technical challenges that needed procedural solutions to maintain rig stability and be economical on resources.

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