Shaping the Elements: Curvenet Animation Controls in Pixar's *Elemental*

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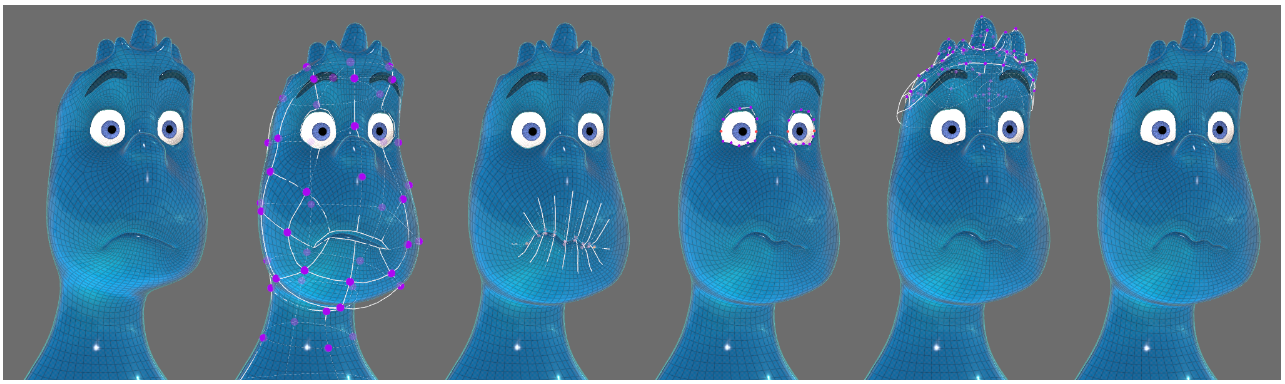

Figure 1: Our new shaping rig provides fine animation controls driven by sparse and modular curvenets that produce detail-preserving surface deformation. From left to right, the face articulation is adjusted sequentially by posing curvenets over the head, lips, eyes, and hair of *Wade*, the water character from Pixar's feature film *Elemental*. ©Pixar.

ABSTRACT

We present a new shaping rig for authoring layers of animation control that facilitate surface editing in shot work. Our approach expands the curvenet rigging technology [de Goes et al. 2022] by introducing new tools that auto-generate a surface-aligned direct manipulator per curvenet knot. As a result, we obtain a mapping from animation controls into curvenet adjustments relative to the deforming surface with minimal setup. We showcase our curvenet shaping rig using results from Pixar's feature film *Elemental* (2023).

ACM Reference Format:
Duc Nguyen, Jeremie Talbot, William Sheffler, Mark Hessler, Kurt Fleischer, and Fernando de Goes. 2023. Shaping the Elements: Curvenet Animation Controls in Pixar's *Elemental* . In *Special Interest Group on Computer Graphics and Interactive Techniques Conference Talks (SIGGRAPH '23 Talks), August 06-10, 2023.* ACM, New York, NY, USA, 2 pages. https://doi.org/10.1145/3587421.3595415

1 INTRODUCTION

The characters of Pixar's feature film *Elemental* (2023) are personifications of the classical elements of water, fire, and air. To capture the fluidity of these elements, our animation team envisioned early on production the need for shaping controls that refine the character articulation within the shot context. Unfortunately, existing techniques to create shot-based animation controls are limited to sculpting and transient rigs, which are often hand-crafted and intricate to setup. In particular, our animators sought a sparse representation that can express subtle shape adjustments, while being easily keyframed and constrained to the deforming surface.

In this work, we present a new shaping rig that provides fine animation controls with minimal setup. Our approach builds on the curvenet rigging technology introduced by de Goes et al. [2022]. By exploiting curvenets, animators have access to modular curve controls expressing surface profiles and layered over the character articulation agnostic to the underlying rig or surface tessellation. Additionally, we devised a new deformer that auto-orients direct manipulators attached to curvenet knots, thus defining animation scopes for rotates, translates, and scales relative to the deforming surface free of any extra rigging setup. Equipped with these tools, the animation team in *Elemental* was able to edit and keyframe character poses with fine shaping controls, while still producing detail-preserving deformations.

2 CURVENETS & PROFILE MOVER

We start by reviewing the concepts of curvenets and Profile Mover on which our work is based. We point the reader to [de Goes et al. 2022] for more technical details. Curvenets are rigging primitives that embody curves with shared points depicting characteristic profiles of the surface to be deformed. Unlike cages or patches, curvenets can represent multiple surface parts with no modeling or

SIGGRAPH '23 Talks, August 06-10, 2023, Los Angeles, CA, USA

ACM ISBN 979-8-4007-0143-6/23/08.
https://doi.org/10.1145/3587421.3595415

meshing restrictions (see, e.g., Figure 1). Artists construct curvenets by drawing Bézier splines near the character surface and then articulate their knots and tangents using traditional rigging tools. As a result, curvenets simplify the rig with orders of magnitude fewer authored points, while separating the articulation setup from the surface tessellation. To compute the surface deformation, curvenets are accompanied by a custom deformer, the *Profile Mover*, that interpolates the curvenet deformation over the surface mesh. At its core, the Profile Mover implements a mesh cutting algorithm that binds curvenets to the surface mesh, followed by a mesh optimization that reconstructs surface details conforming to the posed curvenets.

The curvenet technology was first deployed in Pixar's *Turning Red* (2022) for articulating both the body and the face of the Panda characters. Since the Panda rigs were entirely based on curvenets, animators quickly extended the curvenet setup into a shot-based interface for additional animation shaping, in which curvenet knots were sculpted interactively while still triggering the same Profile Mover. However, in our original implementation, adding animation controls over curvenets required a manual stitching setup with artists creating and fitting handles to the location and orientation of each curvenet knot. Despite this troublesome setup, curvenet animation controls had a significant impact in shot work, replacing tedious mesh sculpting with a few curvenet adjustments.

3 SHAPING THROUGH CURVENETS

To ease the authoring of shaping rigs in *Elemental*, we designed a new workflow for promoting curvenets into animation controls that bypasses the need of any manual setup. We first enabled the superposition of the Profile Mover deformations on arbitrary rig configurations. To this end, we made a small modification to our

Figure 2: Our curvenet animation controls were used to shape the fire character *Ember* and a prop molten glass asset. The top image illustrates the deformation generated by Curvenet Adjustments with knots displayed as purple spheres, while the bottom image shows the final render. ©Disney/Pixar.

deformation algorithm that accounts for different projection and rest poses of the input surface mesh. The projection pose is set to a neutral surface shape (e.g., T-pose) onto which curvenets are bounded, while the rest pose represents the result of any surface deformation performed before the curvenet articulation. Since the projection pose is persistent throughout the animation, we can precompute the curvenet binding only once, thus keeping the computational cost of Profile Mover intact. Additionally, we ensure that curvenets track the character animation by warping their knots from the projection to the surface rest pose on every frame.

Our shaping workflow is centered on the *Curvenet Adjustment*, which is a new primitive that defines the animation scope associated with any curvenet knot chosen to be exposed to animation. By default, Curvenet Adjustments have built-in direct manipulators for translate, rotate, and scale that are activated when the adjustment is selected. This primitive also has configurable attributes allowing tangent points to be attached to a parent knot and animated by tangent translate controls. Lastly, we developed the *Curvenet Adjuster Mover* as a new deformer that positions the knots and tangents of the curvenets by evaluating the animation controls encoded through the Curvenet Adjustment primitives. Importantly, this deformer converts the animation controls into world-space transformations by computing an orientation for every curvenet knot. To achieve this goal, we identify a curvenet intersection as any knot shared by three or more curves, and then estimate the rotation that best fits the tangents incident to each intersection from the original curvenet shape to its warped pose. For the remaining knots, we compute the parallel transport of the rotation matrices from every nearby intersection. When a knot lies in between two intersections, we further blend the transported rotations weighted by the inverse distance between the knot and each intersection. This computation occurs at deformation time and takes into account the result of every deformer that has fired on the curvenet before the Curvenet Adjuster Mover, resulting in an orientation that is relative to the deformed surface. Using these auto-generated orientations, we can expose surface-relative curvenet controls to animators without any manual setup, while still executing the Profile Mover to propagate curvenet edits into surface deformations.

4 RESULTS

We implemented our curvenet shaping rig in Presto and integrated it to every fire, water, and air character in *Elemental*. The supplemental video presents interactive sessions demonstrating our curvenet tools in action refining the character performance. Figure 1 breakdowns a series of curvenet adjustments applied to a face expression. Notice how these curvenets were authored with different layouts fitted to surface profiles, including curves resembling coarse cages (e.g., head and hair) versus partially connected and floating curves (eg., lips and eyes). In addition to character surfaces, our curvenet animation controls were also employed to manipulate the shape of props within shot sequences, thus avoiding the need of any custom prop rigging. Figure 2 shows the result of our curvenet tools used to animate a character body as well as a molten glass.

REFERENCES

Fernando de Goes, William Sheffler, and Kurt Fleischer. 2022. Character Articulation through Profile Curves. *ACM Trans. Graph.* 41, 4, Article 139 (jul 2022), 14 pages.