

Hypertextural Garments on Pixar's *Soul*

Jonathan Hoffman
Pixar Animation Studios

Matt Kuruc
Pixar Animation Studios

Junyi Ling
Pixar Animation Studios

Alex Marino
Pixar Animation Studios

George Nguyen
Pixar Animation Studios

Sasha Ouellet
Pixar Animation Studios



Figure 1: Frequent close-ups shots of our characters inspired an expansion of our garment toolbox. ©Disney/Pixar

ABSTRACT

The art direction of *Soul*'s version of New York City sought a highly detailed "hypertextural" style to contrast the ethereal volumetric world our characters visit later in the film. Many New York City shots were extreme closeups of main characters playing various instruments. This meant extreme closeups of our main characters' various garments. The *Soul* characters team identified that increasing the detail of our garment assets heightened the separation between the two worlds. To help establish this highly detailed look, the team developed a render-time deformation pipeline for geometric thread detail.

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1 BACKGROUND

At the beginning of production, artists began to experiment with building thread geometry in Houdini as sources for fabric textures. A library of tileable looks was developed for artists to reference into their materials. These looks included felt, satin, knit, twill, plain weave, and Herringbone weave. Render-time generated fuzz curves were then attached to most garments to provide break up for the silhouette and illumination (a technique internally employed since *Inside Out*). Some artists (having seen the geometric representation of garment threads in Houdini) began exploring replacing the entire garment surface with per thread curve geometry for even more detail. Garment patterns could be generated in the uv-space of the garment, cut out using the uv-map, and reassembled into a 3-D pose.

However, this representation was incompatible with our surface based cloth simulation pipeline. Additionally, caching out per-frame thread data was undesirable as a single frame of our main character turtleneck contained over seventeen million control vertices. Our hair pipeline had recently experimented with a fully cached solution, so we had recent experience with I/O bottlenecks created by assets with millions of per-frame control vertices. An approach for generating patterned fabric threads at render time was previously developed on *Brave* [Child and Thompson 2012], but resurrecting that pipeline would limit our artists' flexibility to a subset of what their Houdini workflow now offered.

2 RENDER-TIME DEFORMATION

A hybrid pre-cached and render-time solution was developed to solve this problem. We cached only the rest pose generated in Houdini and developed a render-time deformation pipeline to warp the threads using the tangent space of the garment's subdivision surface representation. Thread vertices were projected onto the garment surface during the rest pose export, storing the face index and face uv of the closest point. As threads were laid out using a garment's uv-map, it usually made sense to compute this projection in uv space rather than pose space to prevent misprojection artifacts. This warp was implemented as a Katana plugin using coordinate frames computed at the limit surface via OpenSubdiv [Pixar 2012] adaptive refinement. As an optimization, subdivision weights were shared between the rest pose and all motion samples. Threads were ultimately rendered as nonperiodic b-splines. To preserve endpoint interpolation, phantom end points were generated on the fly post-deformation.

Once the basic knitted garment pipeline landed, the deformer was extended to support a variety of garment authoring strategies, each with their own challenges. Crocheted hats had no 2-D layout, requiring a 3-D spatial projection to map the threads to the underlying surface. For sequins, we added support for point instanced geometry. Flyaway threads required a root-based rigid transformation instead of the per point warp employed elsewhere.

Assets were setup by referencing the Houdini representation using Universal Scene Description [Pixar 2015]. A custom schema for describing the parameters of the deformation was developed. We leveraged USD variant sets so that the upstream animation and simulation pipeline only saw the surface representation of the garment. Only in the rendering context of Katana would we flip the variant to enable the detailed threads, limiting what we needed to teach about this alternative garment representation.

3 CONCLUSIONS AND FUTURE WORK

The visual needs of *Soul* provided an opportunity for us to greatly expand our garment shading toolbox. Our Houdini thread texture pipeline inspired the development of a render-time deformer for garments needing more detail than a material alone could provide.

Overall, art responded positively to this detailed look. Shading artists often found it easier to shade a consistent geometry type and material model than the hybrid surface / fuzz curve solution. Additionally, simulation artists found themselves less constrained by the specific geometry requirements (such as modeled foldovers along the sleeves of thick garments), as their simulated meshes were no longer the final rendered representation. One artist even found that for sheer garments, the threads as curves representation provided for a more natural look than the refractive surfaces previously employed. Rendering performance was measured with an early test version of our main character's black turtleneck with the threads as curves version being roughly equivalent to a displaced subdivision surface representation. (The curve representation rendered slightly faster while using slightly more memory than the surface.)

Our render-time deformation solution supported a multitude of Houdini-based garment authoring techniques without the storage

and network requirements of fully cached approach. This experimental pipeline was used on ten hero garments to mitigate risk given the short production schedule and complicated systems requirements for the volumetric soul world. This limitation guaranteed that garment rest poses would be limited to about one percent of our network caches in the worst case. We anticipate that future shows will not impose these same restrictions.

One ongoing challenge is denoising the geometric representations of garments. Our machine learning-based denoiser didn't have this new representation in its training set, sometimes resulting in lost mid-ground detail. We also hope to provide better upstream visualization via the Hydra imaging pipeline bundled with USD.

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