Building A Dynamic Dad

Kristopher Campbell
krc@pixar.com
Pixar Animation Studios

Jonas Jarvers
jjarvers@pixar.com
Pixar Animation Studios

Figure 1: *left* Full Scale Model *middle* Tetrahedral Volume with Layered Cloth *right* Production Frame ©Disney/Pixar.

ABSTRACT

In Pixar's *Onward*, the character Dad had an upper half which consisted of a stuffed hoodie, puffy vest, and garden gloves. The arms were floppy, stuffed sleeves able to swing freely while the head was a cinched, stuffed hood topped with a cap and wearing sunglasses. His lower body was rigged and simulated like a typical character. Knowing it was unrealistic to hand-animate the loose swinging arms and squishy upper body for a feature-length project, we developed a hybrid simulation/animation rig using tetrahedral volumes with complex rest state deformation and animatable targeting. This resulted in a robust, iterative workflow where simulation and animation were used together.

KEYWORDS

Character, Rigging, Cloth, Volumes, Simulation, Animation

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1 INTRODUCTION

In the film *Onward*, the character Dad presented unique challenges for character building, garment tailoring, shot animation, and simulation. His lower half used conventional character construction, with an articulated body and simulated pants, while his upper body was made of a stuffed hoodie and puffy vest. He also needed to be able to pass as a person wearing a sweatshirt if you didn't look too closely. We knew it would be unrealistic to hand-animate the squishy body and floppy arms and head for an entire feature film. To solve this problem, we developed a simulation and animation setup that could be completely dynamically simulated and/or key-frame animated, as well as be able to disconnect from the lower body. The design and construction involved full-scale models, motion-capture, tetrahedral volume and cloth simulation, and a complex rest state rig with many controls.

2 DESIGN

When we started building Dad, we knew his basic requirements as described above. We didn't know the specifics, such as how tightly stuffed he was, how we would hide the opening of the hood, or if the swinging arms were going to be distracting or hilarious. To answer these questions, we built full scale models (Figure 1 *left*), strapped them in baby carriers, and ran around a motion-capture stage, filming and capturing motion data. We learned that we wanted nonanatomical arm bulges and a softer section at mid-chest so the body could flop front to back. Armed with our references, we got to work on the computer, experimenting with different head and arm shapes, sleeve lengths, and material properties for the stuffing as well as the cloth.

3 CONSTRUCTION

Dad's upper body needed to be hand animated in some shots and be completely simulated in others. We also knew that there would be many shots that transitioned from one state to the other. With this in mind, we built a versatile rig.

Traditional upper torso and arm rigs served as base controls for the upper body. Separate knot spline rigs were constrained to each arm allowing overlap, curvy shapes and nonanatomical posing (Figure 2). The upper body geometry was articulated to keep a simple shape language, but also needed to preserve volume. Hierarchical armature joints were used in the upper body rig. This allowed animators to use a procedural overlap system on the upper body and arms. By using a layered approach for different complexities of control, both animators and simulation artists could access the level of control they needed at any time.

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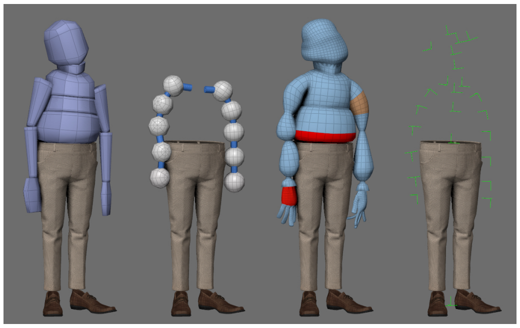

Figure 2: Dad had several different animation control guides. ©Disney/Pixar.

The body simulation needed to be soft, allowing it to bend anywhere and compress if it was squished into a tight spot. The upper body needed to separate from the lower body in a few shots. Keeping all of that in mind, we built a simulation rig using tetrahedral volumes to represent the stuffing, with traditional cloth garments layered on top (Figure 1 *middle*). The garments and stuffing were simulated at the same time in our proprietary cloth and volume solver Fizt[Baraff and Witkin 1998][Baraff et al. 2003][Smith et al. 2019]. To keep the arms from looking too stretchy but sill maintain their flexibility, we anisotropically increased stiffness down the length of the arms using volume fibers[Kim et al. 2019].

In order to hit the poses that animation needed, the underlying rest state of the stuffing needed to be animated. This was done by driving a rest state rig with the animation data of the character. If too much of the animation was applied to the rest state, the simulation could look non-physical, so the amount of animation to be applied was weighted by region and animatable in shots (Figure 3). We also built region-based targeting controls with color-coded guides (Figure 2). Color codes indicated which part of the simulation would be targeting the key framed animation and which would be fully dynamic.

We also came up with a system to bake the simulation back into key frame animation. This could be used as the final animation of the upper body, or as a input when running new simulations. A set of simulation pivots in the rig served as target spaces for the joints (Figure 2). A second set was posed by the simulation. The transforms from the pivots posed by the simulation were baked into the target pivots per frame. Then the character joints were constraint to the target pivots in order to pose the character to match the simulation output. At that point we unconstrained the joints with compensation, so that the world-space positions were translated into local rotations and positions.

The last bits of complexity in Dad were his hat and sunglasses, which could not be fully animated because the position of Dad's head was determined by the simulation. To allow the simulation to move freely, these two rigid objects were constrained to the output of the simulation. Additional position tweaks could be applied post simulation.

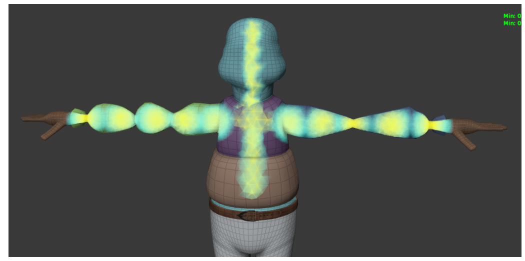

Figure 3: Weighted regions controlled where the simulation targeted the animation. ©Disney/Pixar.

4 PRODUCTION

Making Dad move in a physically plausible way and still hit timing and posing was a challenge. With too much posing we lost the feeling of a rag doll, but with only simulation we were not hitting comedic and emotional beats. To find the right balance, Simulation artists worked directly with character animators to bring Dad to life.

Character animators would work on Dad's lower half just like they would on any other character, progressing from blocking to final polished animation. Dad's upper body required a different approach. Blocking could be handled in the traditional way, posing the arms and head to get the acting ideas across. But we found that adding animated overlap or complex shape changes could introduce unwanted motion in the final simulated character. While some shots could be primarily animated, most had a significant amount of simulated motion.

The simulation needed to be directable. Specific shapes were sculpted to flow in and out of simulation. For example, a hand would be pulled toward the animated hand's position with spring forces for part of a shot and then be allowed to swing freely for the remainder of the shot. Wrinkles in the fabric were enhanced or smoothed. To get Dad's eye line in just the right place, simulation artists used post simulation sculpting and posing to alter shapes and change the angle of his head. Rest states were animated to meet the needs of specific shots, causing the simulation more closely match the animation.

5 CONCLUSION

The requirements of this setup, while complex were essential to getting the directed yet physically believable acting of Dad in the film. His simulation proved to be a crucial element to the final performance of his character on the screen.

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