Mixing dynamics and blend shapes for the Hulk

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1. Introduction

The Hulk was one of the more challenging characters to rig in Marvel's The Avengers because his muscular anatomy is featured so prominently. Muscle rigging is often separated into simulation-based muscle systems and deformer or shape-based techniques; however, each of these techniques has significant drawbacks. To have the best of both worlds, we created a hybrid approach that was fully dynamic and fully art-directable.

2. Issues with non hybrid techniques

Though physically based **dynamics** have the potential for incredible realism, simulating muscles and skin is computationally very expensive and artistic control is indirect. The dynamic attributes can be tweaked to adjust the look, but iterating on the results is long and much time is spent perfecting internals that are never rendered. To solve the computational issues and allow the surface to be manipulated directly, the simulation is sometimes baked into shapes and controlled by a fast Pose-Space (PSD) interpolator, but the dynamic properties are then lost.

Deformers can also be used to create a non-simulation based muscle system that mimics some simulation properties such as volume preservation, collision [sliding] and secondary motion. Though relatively fast, this technique can lack both the realism of a true simulation and can limit the art-directablity of PSD shapes.

As a contrast, **shapes** allow very precise control over the look of a character but at the expense of any secondary motion. Since shapes are limited by what is bound in the PSD system, realistic muscle jiggle is usually forfeited for this fast, art-directable technique.

3. Our hybrid approach

For The Hulk, animators worked with a simplified rig, then a complex deformation rig is swapped in at animation-export time.

3.1 Muscles

We start the muscle rig with simple muscle primitives: a nurbs curve with many cross-section frames, defining an implicit surface around it. The volume of the muscles can be adjusted at rest. Then the position and scale of the cross sections will be calculated to preserve the volume of the muscles while the attachment points of the curve mimic the origin and insertion of muscle bodies. These volume preserving cross-section transforms become the skinning influences for the final hi-res surface.

3.2 Deformations and blend shapes

Because the final geometry is ultimately deformed by linear blend skinning, we can easily add artist-created pre-skinning blend shape deformation. With all muscle influences active, we can pose our model according to various calisthenics and correct or enhance problem areas with shapes. These shape deltas are inverted through the skinning and then bound to our custom joint driven blend shape system. Once this is done, the system will automatically determine which shapes should be triggered for the current pose of the character. Since the many influences contribute heavily to the look of the surface, the corrective-shape deltas are relatively small and only a small number of poses are needed to provide stable interpolation between shapes. In addition, we augment the surface with custom sculpt deformers for things that are difficult to shape, such as bones/tendons that protrude or slide under skin. Finally, we examine edge lengths to relax and smooth imperfections.

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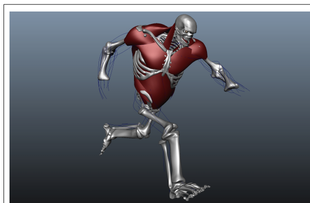
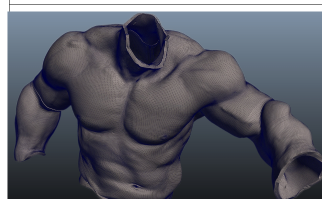


Initial rig with bones

Muscles primitives

Jiggle Bodies

Polygonal muscles



Skin Layer

Final hi resolution model

3.3 Jiggle dynamics

Often jiggle dynamics are non-simulation based, but this can lead to a loss of volume as simple muscles or transforms jiggle beyond physical limits such as bones or other muscles. To solve this problem, we created fast dynamic tetrahedral meshes that represent muscle groups and embedded our skin influences into this volume. This has the advantage of not needing to solve collisions between primitives since we assume the muscles are surrounded by skin and thus move as a unit. These lo-res tet-meshes are first enveloped by the muscle influences and then constrain the same influences when the simulation is computed, thus transferring the motion to the outer surface through skinning. Corrective and PSD shapes simply go along for the ride because they are computed pre-skinning. Since this is a true simulation, parameters can be adjusted to constrain muscles to bone, give different muscles more weight and stiffness and can be tied into animator-controlled flex shapes.

3.4 Extra Inner/outer layers

For around 10% of the shots we also added an outer layer, in the form of a thin multi-level tetrahedral mesh, constrained to the muscle simulation. Since this dynamic tet-mesh is an exact representation of the outer surface with thickness, it allows a very fine level of jiggle dynamics, wrinkling and the ability to target the sculpted surface details exactly. The skin simulation is very detailed and includes collisions so we limited its use to shots that would benefit from the extra time and attention.

4. Conclusion

We proposed a hybrid approach to approximate a muscular body, mixing artist-created shapes with a fast tetrahedral simulation that affects the creatures' skinning. This approach allows for fine details through artist created shapes, and has fast high-quality secondary motion that can also be used to drive a complex skin simulation.