# Resculptors: Layered Curve-Based Deformers

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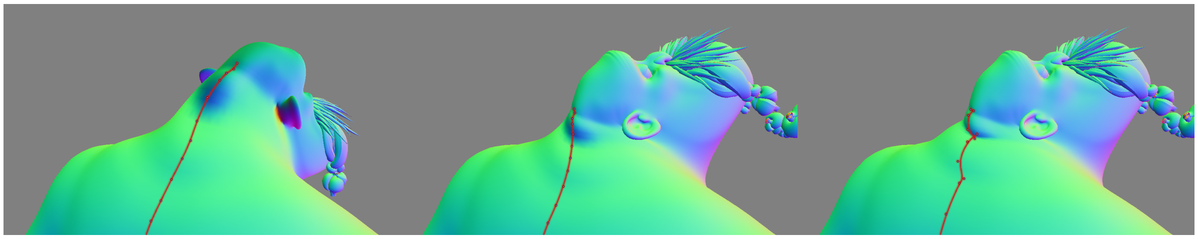

**Figure 1:** *Left: Reference model and resculptor; Middle: Kinematically deformed models; Right: Resculpted models providing neck bulge*

## 1 Introduction

Resculptors are curve-based deformers that easily layer on top of kinematic deformations. They provide a simple mechanism to apply soft-tissue deformations, compensate for volume changes, enhance anatomical details, and achieve specific art direction. They are easy to set up, fast to evaluate, require no weight assignment, and provide a high level of procedural control.

## 2 Background and Related Work

Kinematic deformation techniques such as linear blend skinning, dual quaternion skinning, and offset curve deformation provide basic control of a model in response to a poseable skeleton. These techniques provide gross movement, but often lack the precision and control required to achieve desired shapes.

To achieve finer control, secondary deformation techniques such as FFDs, pose-space offsets, and wires [Singh and Fiume 1998] are typically used. Our work is rooted in many of the same observations that led to the development of wires. However our method differs from and improves upon wires in several key ways:

1. Easily supports layering on top of existing deformations
2. Generates smooth, "fleshy" deformations without weight painting
3. Provides art-directable compensation for volume changes
4. Can simulate skin-sliding effects via arclength parameterization

## 3 Implementation

At bind time, an association is made between every vertex of model $M$ and resculptor $R$. This includes a parametric location on $R$, a distance- and curvature-attenuated weight for primary deformation, and a distance-attenuated weight for a volume-change compensating deformation. This calculation is computationally expensive, but is typically performed once in the reference state of the character.

Users tune a sparse set of parameters to control the deformation influence, including a maximum falloff distance and maximum falloff curvature. In the most common configuration, these distances and accumulated curvatures are measured geodesically, and are attenuated using Gaussian functions, producing a deformation falloff that feels elastic, coherent, and "fleshy".

Similarly, to control the secondary volume-compensating deformation, users specify an envelope value and maximum falloff distance. This distance is attenuated by a Gaussian function multiplied by a quadratic function, producing a flattened-donut shape.

$$x^2 (e^{\frac{-x^2}{\sigma^2}}) \quad (1)$$

At deformation time, model $M$ is deformed using standard kinematic techniques. Likewise, resculptor $R$ is deformed by the kinematically-deformed $M$ using standard wrapping techniques.

$R$ is then procedurally *resculpted* using techniques such as pose-space offsets, relaxation, simplification, linearization, or dynamic simulation. The variety of techniques available to efficiently modify curve shapes provides a great deal of power, flexibility, and extensibility.

Finally, model $M$ is deformed using the difference between the kinematically-deformed $R$ and the *resculpted* $R$. The primary deformation is applied using simple vector offsets. Each vertex of $M$ is transformed by the difference between the evaluated curve positions at the parameters recorded at bind time. Convincing sliding effects can be achieved by using arclength parameterizations of $R$ in its intermediate states.

Optionally, a secondary deformation is applied to compensate for volume changes. This deformation is applied along the vector between a given vertex of $M$ and its associated position on $R$, projected onto the plane defined by the normal direction of $R$, producing an art-directable bulge or pinch.

## 4 Experience

Resculptors have been used extensively in all characters of *How to Train Your Dragon 2*. They have proven to be a valuable tool to create high-quality character deformations quickly.

## References

SINGH, K., AND FIUME, E. 1998. Wires: A geometric deformation technique. In *Proceedings of the 25th Annual Conference on Computer Graphics and Interactive Techniques*, ACM, New York, NY, USA, SIGGRAPH '98, 405–414.