A Simple Approach to Interactive Free-Form Shape Deformations

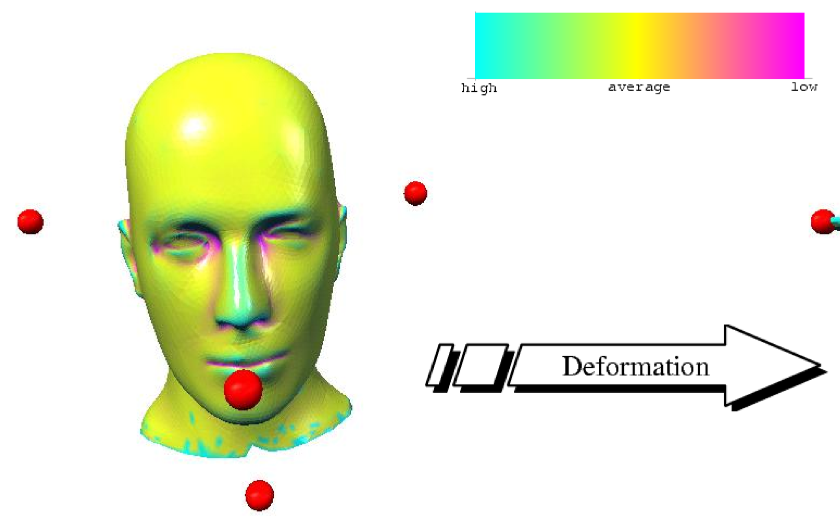
Shin Yoshizawa — shin@mpi-sb.mpg.de

Alexander G. Belyaev — belyaev@mpi-sb.mpg.de

Hans-Peter Seidel — hpseidel@mpi-sb.mpg.de

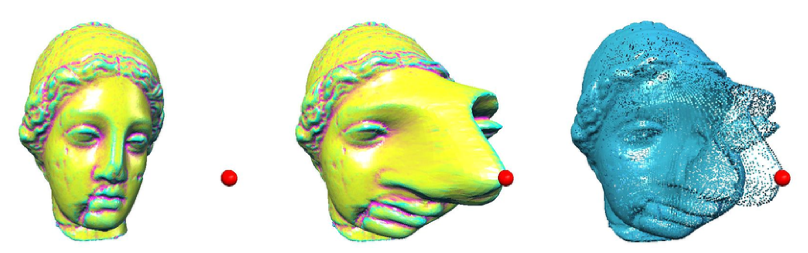
Interactive Free-Form Shape Deformations

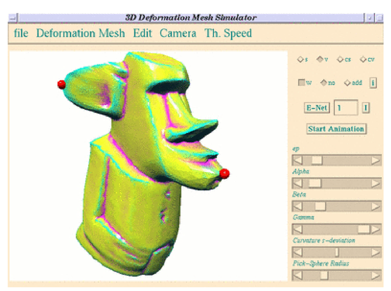
Interactive and intuitive free-form shape deformations manipulated via positions of control points. Coloring by mean curvature demonstrates high quality of deformations.



Contribution

- **Simple and Fast Deformation Method**
- Can be applied to *Point Set Surfaces*
- Rich palette of free-form deformations
  - Constrained, Directional and Anisotropic
- Java3D program: Free-Form Shape Deformator is available at www.mpi-sb.mpg.de/∼shin/Research/DefMesh/DefMesh.html





Control Mechanism

Basic Shape Deformation Idea with Virtual Control Point

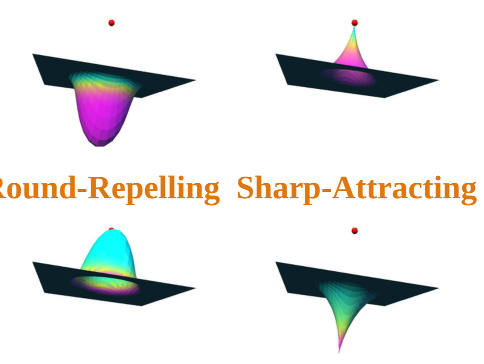
Given a mesh and a control point $\mathbf{C}$, let us shift a mesh vertex $\mathbf{O}$ into its new position $\mathbf{P}$ defined by $\mathbf{P} = \mathbf{O} + \mathbf{D}(\mathbf{C}, \mathbf{O})$, where the displacement $\mathbf{D}$ and the weight $\mathbf{W}$ are given by

$$\mathbf{D}(\mathbf{C},\mathbf{O}) = \frac{\gamma}{\sigma}\mathbf{W}(\mathbf{C},\mathbf{O})(\mathbf{O}-\mathbf{C}), \quad \mathbf{W}(\mathbf{C},\mathbf{O}) = exp(-\frac{|\mathbf{C}-\mathbf{O}|^{\alpha}}{2\epsilon^2}), \quad \sigma = W(\mathbf{C},\mathbf{O}_{min}).$$

Here $\mathbf{O}_{min}$ denotes the mesh vertex closest to $\mathbf{C}$. The $\gamma = -1$ and $\gamma = 1$ lead to different shape deformations: round-repelling when $\gamma = 1$ and sharp-attracting when $\gamma = -1$ via the standard control point.

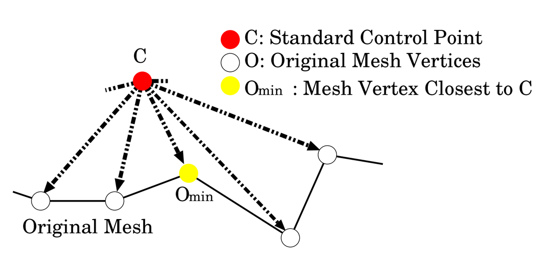
In order to obtain a round-attracting and sharp-repelling deformations a concept of a virtual control point is introduced. The virtual control point $\mathbf{V}$ is obtained from $\mathbf{C}$ by the reflection with respect to $\mathbf{O}_{min}$. Then the following displacement filed is used.

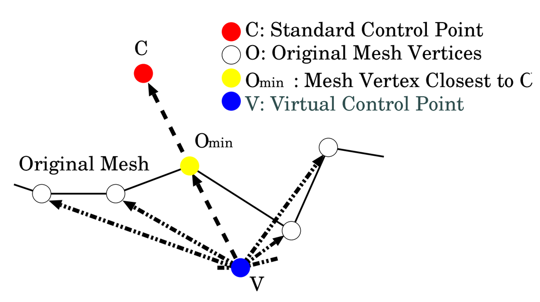
$$\mathbf{D}(\mathbf{C},\mathbf{O}) = \frac{\gamma}{\sigma}\mathbf{W}(\mathbf{C},\mathbf{O})(\mathbf{O}-\mathbf{V}), \quad \mathbf{V} = 2\mathbf{O}_{min} - \mathbf{C}.$$



Round-Repelling Sharp-Attracting

Round-Attracting Sharp-Repelling

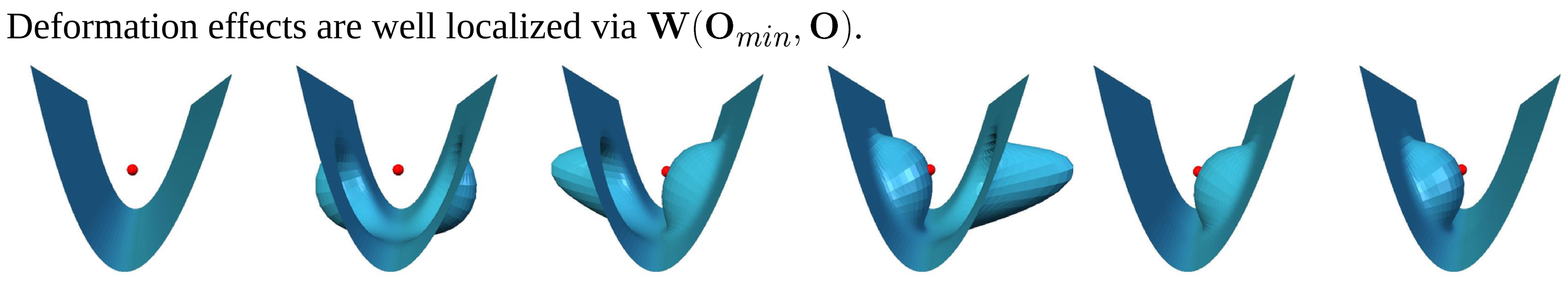




Advanced Deformation Techniques

Constrained Deformation

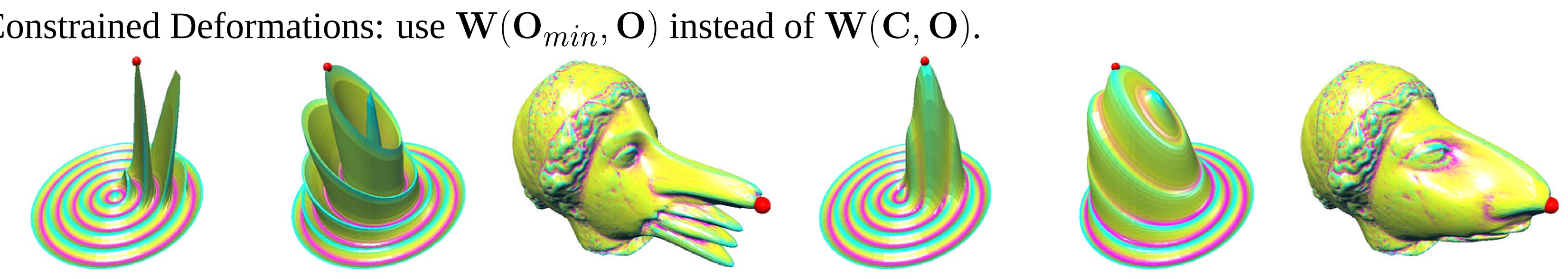
Deformation effects are well localized via $\mathbf{W}(\mathbf{O}_{min}, \mathbf{O})$.



Original Round-Repelling $\mathbf{W}(\mathbf{C},\mathbf{O})$ Round-Attracting $\mathbf{W}(\mathbf{O}_{min},\mathbf{O})$

Feature Sensitive vs Intuitive Deformations

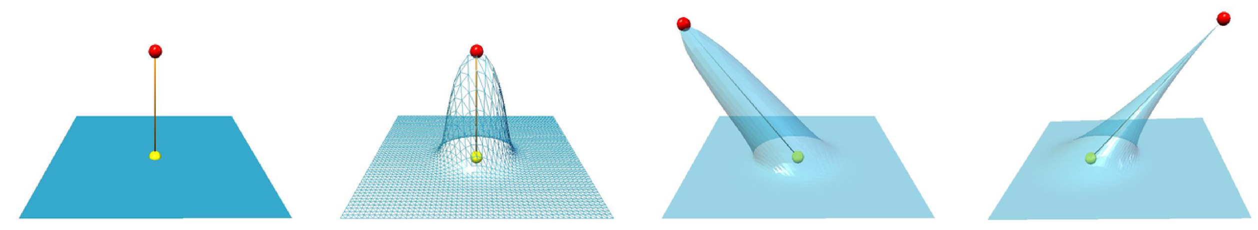
Constrained Deformations: use $\mathbf{W}(\mathbf{O}_{min}, \mathbf{O})$ instead of $\mathbf{W}(\mathbf{C}, \mathbf{O})$.



Feature Sensitive $\mathbf{W}(\mathbf{C},\mathbf{O})$ More Predictable $\mathbf{W}(\mathbf{O}_{min},\mathbf{O})$

Directional Deformation

Directional Deformations via $\mathbf{R}$ (yellow spheres in the images) instead of $\mathbf{O}_{min}$.



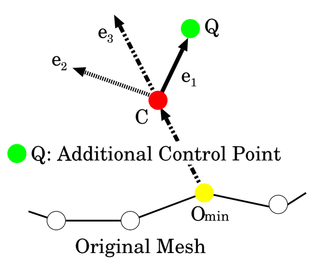
Anisotropic Deformations

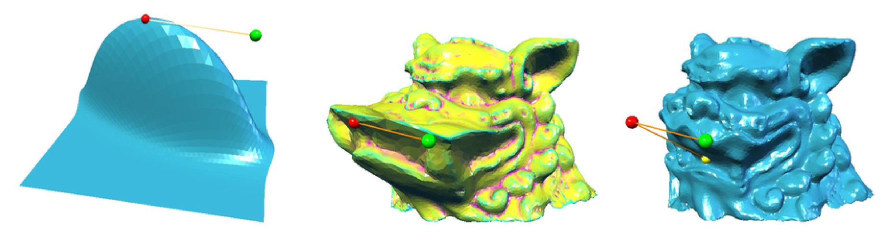
Anisotropy is defined via an additional control point $\mathbf{Q}$ (green spheres in the images), and the weight:

$$\mathbf{W}(\mathbf{C},\mathbf{O}) = \exp(-\frac{|\mathbf{C}-\mathbf{O}|^{\alpha}}{2\epsilon^2}) = \exp(-\frac{|\mathbf{x}^t A\mathbf{x}|^{\frac{\alpha}{2}}}{2\epsilon^2}), \quad \mathbf{x}^t = (\mathbf{C}-\mathbf{O})^t B^t, \quad \mathbf{x} = (\mathbf{C}-\mathbf{O})B,$$

$$B = \{\mathbf{e}_1, \mathbf{e}_2, \mathbf{e}_3\}, \quad \mathbf{e}_1 = \frac{\mathbf{Q}-\mathbf{C}}{|\mathbf{Q}-\mathbf{C}|}, \quad \mathbf{e}_3 = \frac{\mathbf{C}-\mathbf{O}_{min}}{|\mathbf{C}-\mathbf{O}_{min}|}, \quad \mathbf{e}_2 = \mathbf{e}_1 \times \mathbf{e}_3, \quad \text{ex.} g(x) = \frac{1}{10x},$$

$$A = \begin{pmatrix} g(|\mathbf{Q}-\mathbf{C}|) & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}.$$



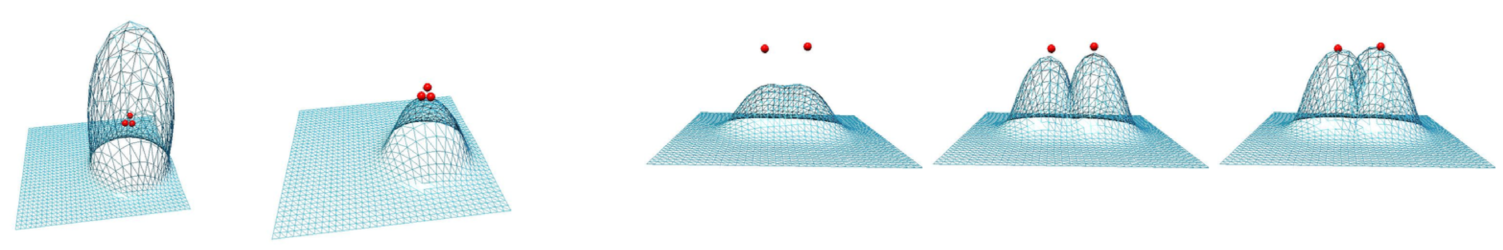


Composite Advance Deformations

Multiple Control Points

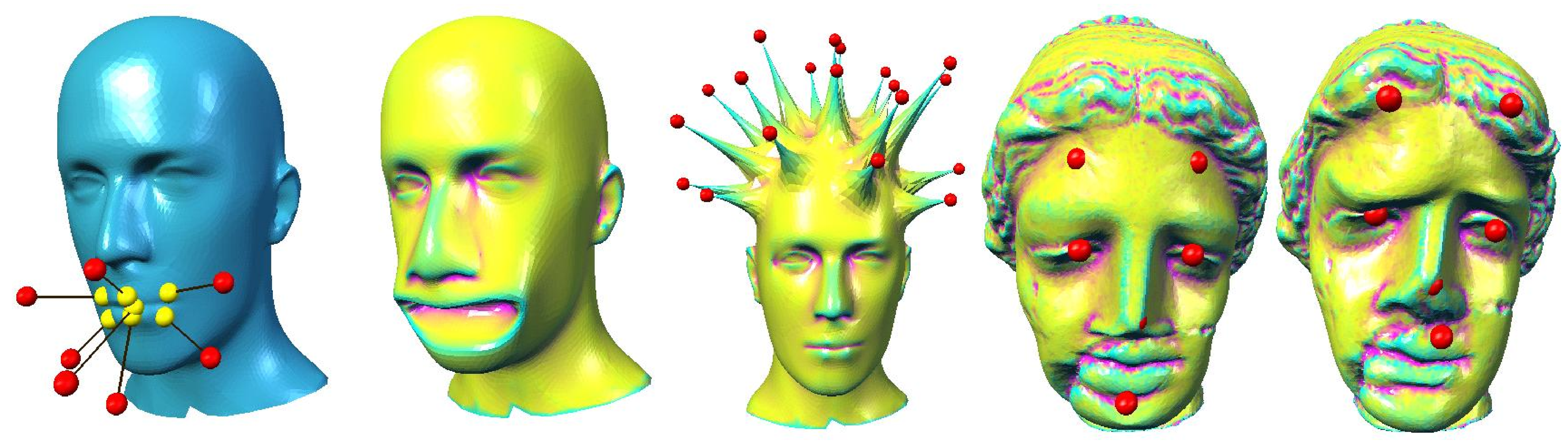
Given a mesh and control points $\mathbf{C}_k$, let us shift a mesh vertex $\mathbf{O}$ into its new position $\mathbf{P}$ defined by the following equations. Each control point can have different properties: standard/virtual, α, γ, ϵ), constrained, directional and anisotropic.

$$\text{Overlapping: } \mathbf{P} = \mathbf{O} + \sum \mathbf{D}(\mathbf{C}_k, \mathbf{O}), \qquad \text{Blending: } \mathbf{P} = \mathbf{O} + \frac{\sum \mathbf{D}(\mathbf{C}_k,\mathbf{O})|\mathbf{D}(\mathbf{C}_k,\mathbf{O})|^{\beta}}{\sum |\mathbf{D}(\mathbf{C}_k,\mathbf{O})|^{\beta}}.$$

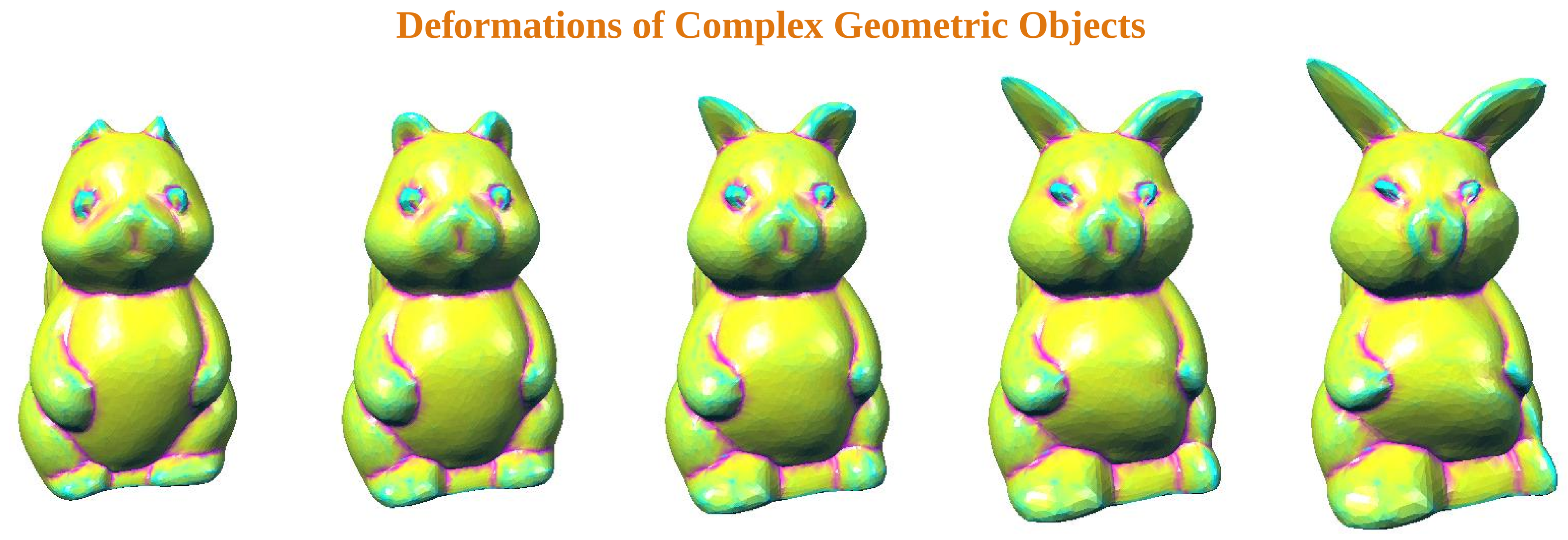


Overlapping Blending Varying β

Having Fun with Free-Form Deformations



Deformations of Complex Geometric Objects

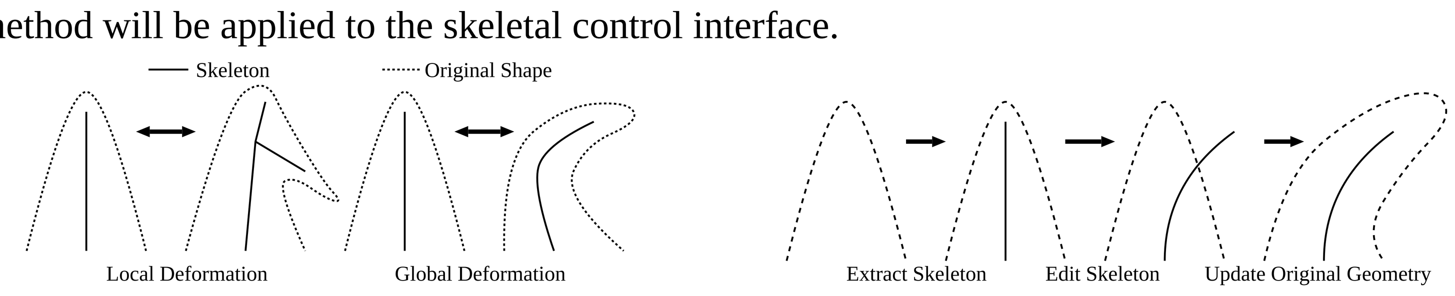


Morphing a squirrel into a piglet

Future Research

Skeleton-Driven Global Shape Deformations

The method will be applied to the skeletal control interface.



Skeleton Deformation Update Geometry