Exact Volume Preserving Skinning with Shape Control

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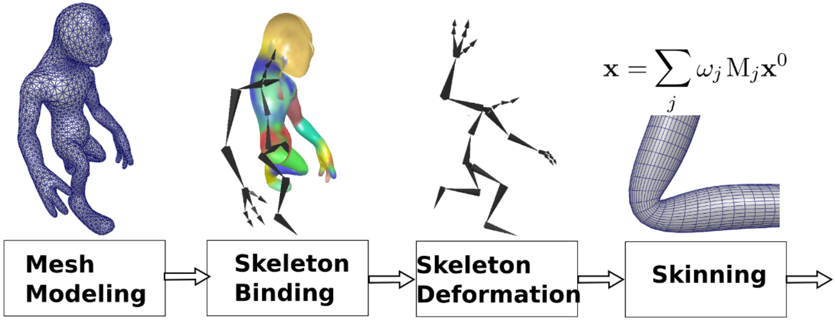
Classical character animation pipeline

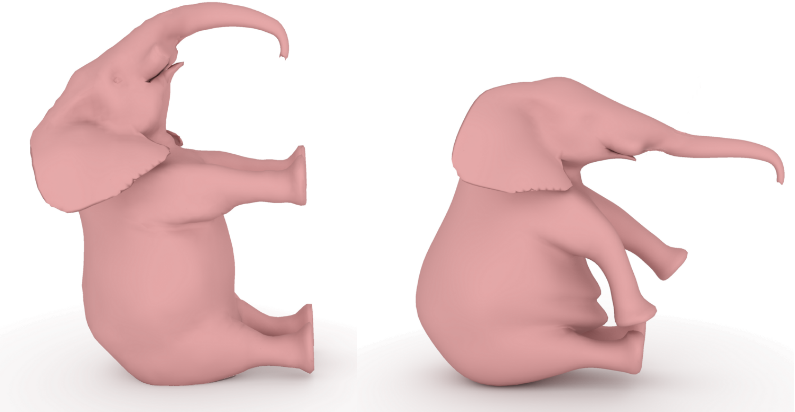
Interactive character deformation

- Skinning deformation
  (Skeleton Subspace Deformation)



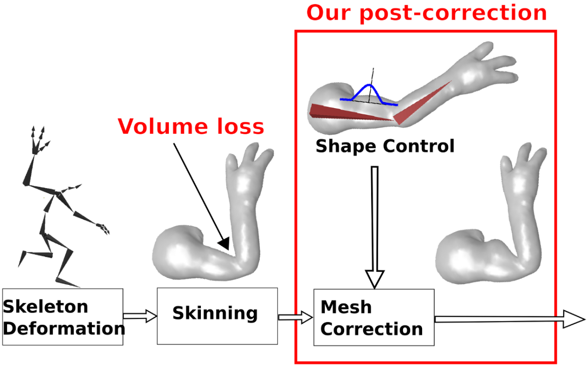
Motivations: character animation

- Fits into the **standard pipeline**.
- **Interactive** deformation.
- **Natural**-looking behavior ⇒ Constant volume.
- Intuitive **control**.



Volume correction: Overview

- **Post-process** volume correction on skeleton deformed shaped.
- **Exact** volume preservation.
- Controlable using **1D profil curve**.



Previous work: Skinning deformation

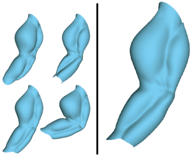
- Training based approaches

  (⊕ Freedom, ⊖ Need of training poses)

  [Lewis *et al.*, SIGGRAPH 2000]

  [Wang *et al.*, SCA 2002]

  [Weber *et al.*, EG 2007]



- Mathematical interpolation improvement

  [Angelidis and Singh SCA 2007]

  (⊕ Constant volume, ⊖ Control)

  [Kavan *et al.* TOG 2008]

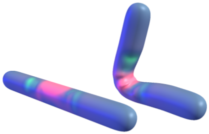
  (⊕ General, ⊖ No constant volume)

- Geometrical constraints

  (⊕ Constant volume, ⊖ Control)

  [Funck *et al.* VMV 2008]

  [Rohmer *et al.* PG 2008]

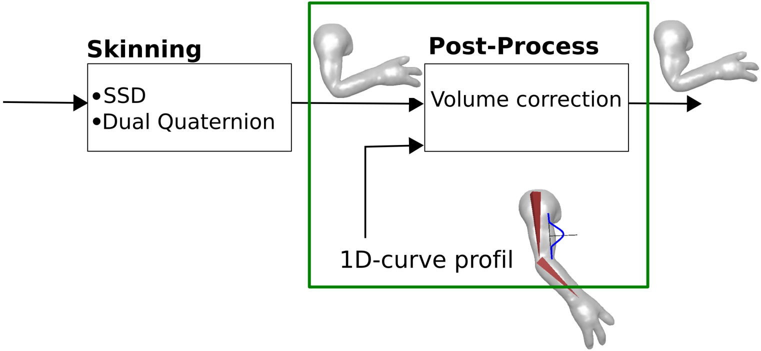


Improvements from our previous work

	[Rohmer *et al.* PG 2008]	Our Method
Constant volume	approximated	exact
Final shape control	skinning weights	1D-profil curve
Deformation space	$\mathbb{R}^N$	$\mathbb{R}^{3N}$
Mesh	triangles	triangles+quads
Overlaping deformation	no	yes

Overview

1. Exact volume compensation
2. Local control of the deformation
3. Application to complex characters



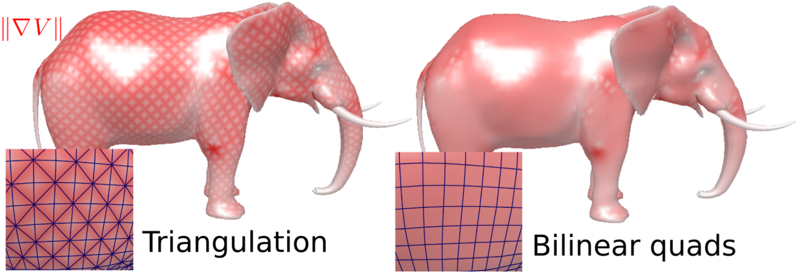
Enclosed volume of the mesh

- Triangular mesh
  [Gonzalez-Ochoa 99]

$$V = \sum_{\text{triangles}} V_t = \sum_{\text{triangles}} z_{avg}\,\mathcal{A}$$

- Quadrangular mesh

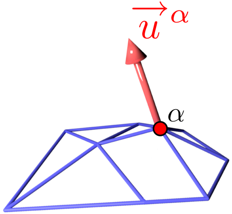
$$V = \sum_{\text{quads}} V_q = \sum_{\text{quads}} \mathbf{z}\,\mathrm{M}\,\mathbf{k}^T$$



Volume correction expression

- Per-Vertex displacement **u**

$$\begin{cases} \text{min} & \sum \|\mathbf{u}\|^2 \\ \text{constraint to} & V(\mathbf{p}+\mathbf{u}) = V_0 \end{cases}$$



- Lagrange multipliers expression

$$\Lambda(\mathbf{u}, \lambda) = \sum_i \|\mathbf{u}_i\|^2 + \lambda \left(V(\mathbf{p}+\mathbf{u}) - V_0 \right)$$

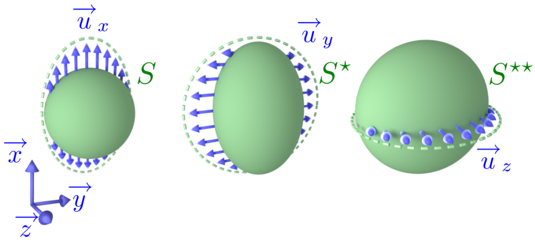
- V is trilinear in $(\mathbf{u}_x, \mathbf{u}_y, \mathbf{u}_z)$.

Exact closed-form correction in 3 steps

- Extend the idea from [Elber, Technion report 2000]:
  1. Deform along x and correct μ_0 % of the volume.
  2. Deform along y and correct μ_1 % of the volume.
  3. Deform along z and correct μ_2 % of the volume.

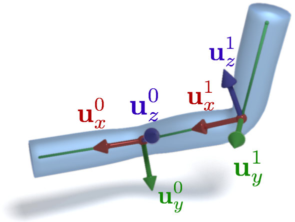
$$\begin{aligned}\mathbf{u}_i &= (u_x, u_y, u_z) \\ &= \Delta V \left(\mu_0 \frac{\nabla_{\mathbf{x}_i} V}{\sum_k \|\nabla_{\mathbf{x}_k} V\|^2}, \mu_1 \frac{\nabla_{\mathbf{y}_i} V^\star}{\sum_k \|\nabla_{\mathbf{y}_k} V^\star\|^2}, \mu_2 \frac{\nabla_{\mathbf{z}_i} V^{\star\star}}{\sum_k \|\nabla_{\mathbf{z}_k} V^{\star\star}\|^2} \right)\end{aligned}$$

$\mu_0 + \mu_1 + \mu_2 = 1 \Rightarrow$ exact volume preservation.



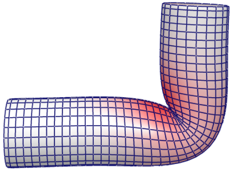
Localizing the deformation

- Use of local frames for each joint.

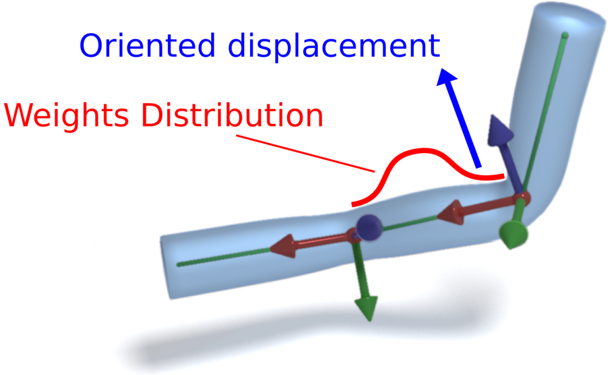


- Use of vertex-displacement weights

$$\begin{cases} \min & \sum_{\text{vertices } i} \frac{\|\mathbf{u}_i\|^2}{\gamma_i} \\ \text{constraint to} & V(\mathbf{p}+\mathbf{u}) = V_0 \end{cases}$$

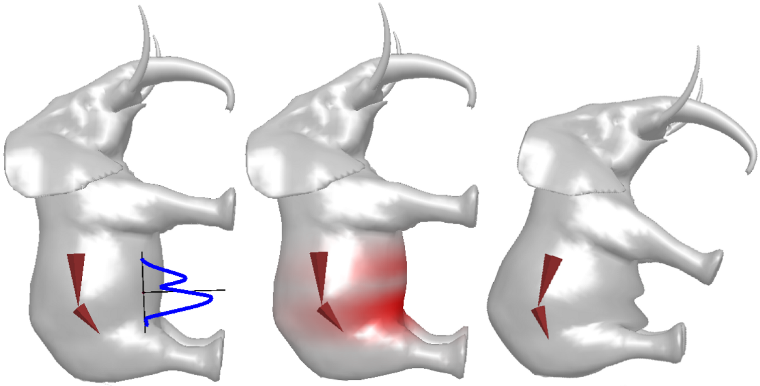


1D-Profil curve

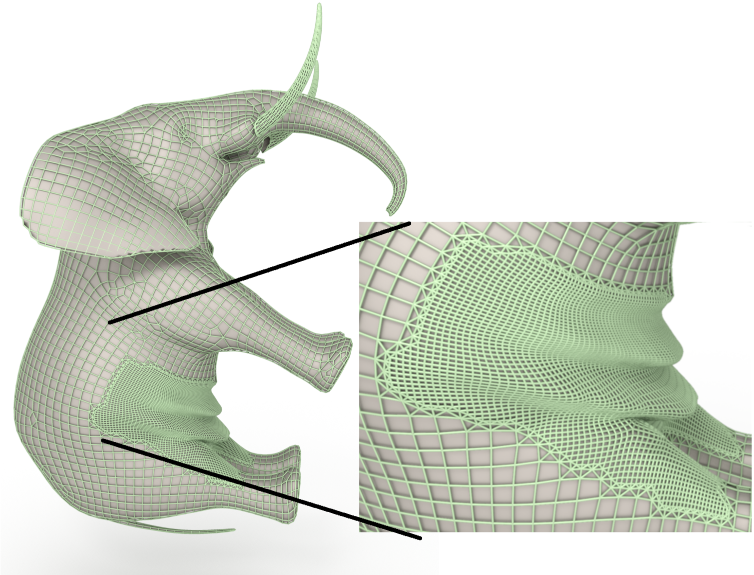


Application to complex characters

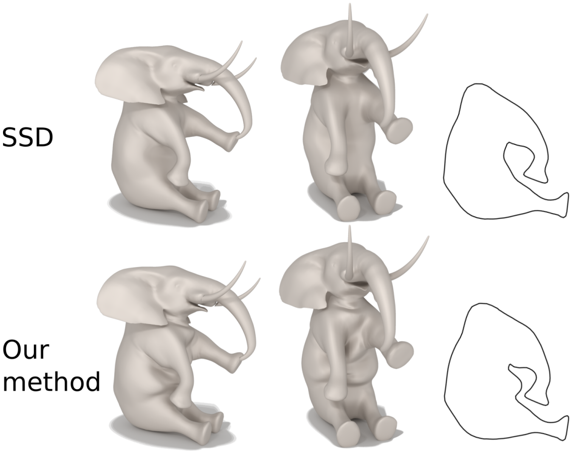
Animal animation



Adaptative refinement

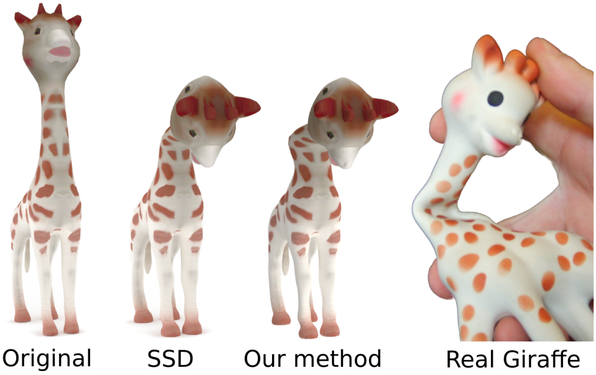


Overlaping deformations



Giraffe deformation

- Rubber effect automatically oriented



Animal animation

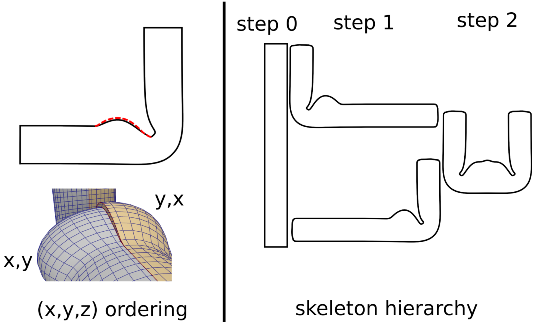
Video

Computational Time

	vertices	joint number	cost
giraffe	1673	1	0.011s
elephant	6646	1	0.053s
subdivided elephant	13439	1	0.110s
elephant	6646	17	0.407s

Limitations

- ΔV is computed globally (computation time).
  - Tradeoff: **Speed VS Local limitations.**
- Ordering in x, y, z deformation ($20\%r$).
- Ordering in skeleton hierarchy ($< 2\%r$).



Conclusion and future work

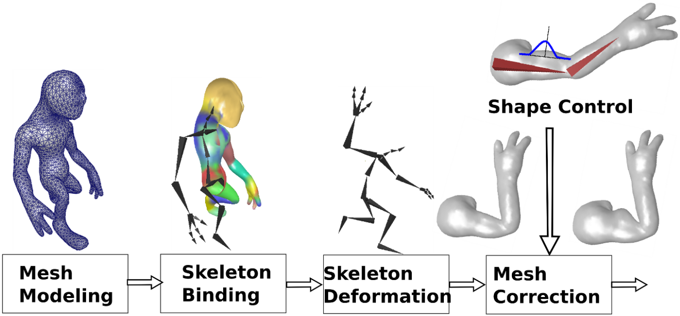
Advantages

- Exact volume preservation.
- Controlability using 1D-curve profil.
- No limitation on locality, overlaping influences.

Future Work

- Build a GUI / Profil sketch.
- Local cutting to compute ΔV locally.
- Self collision.

Thank you



Shape Control
Mesh Modeling
Skeleton Binding
Skeleton Deformation
Mesh Correction