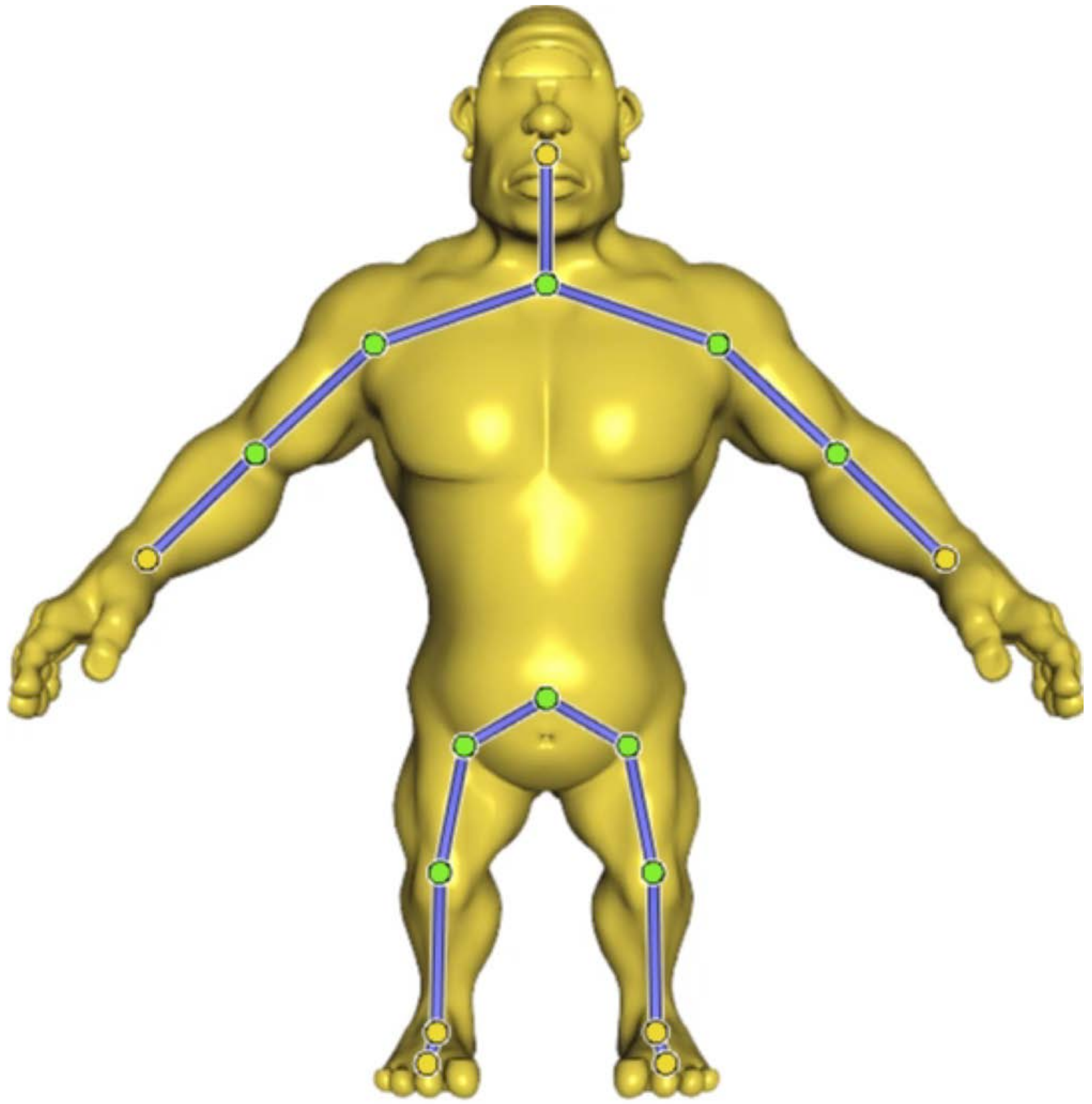
Linear Blend Skinning (LBS)

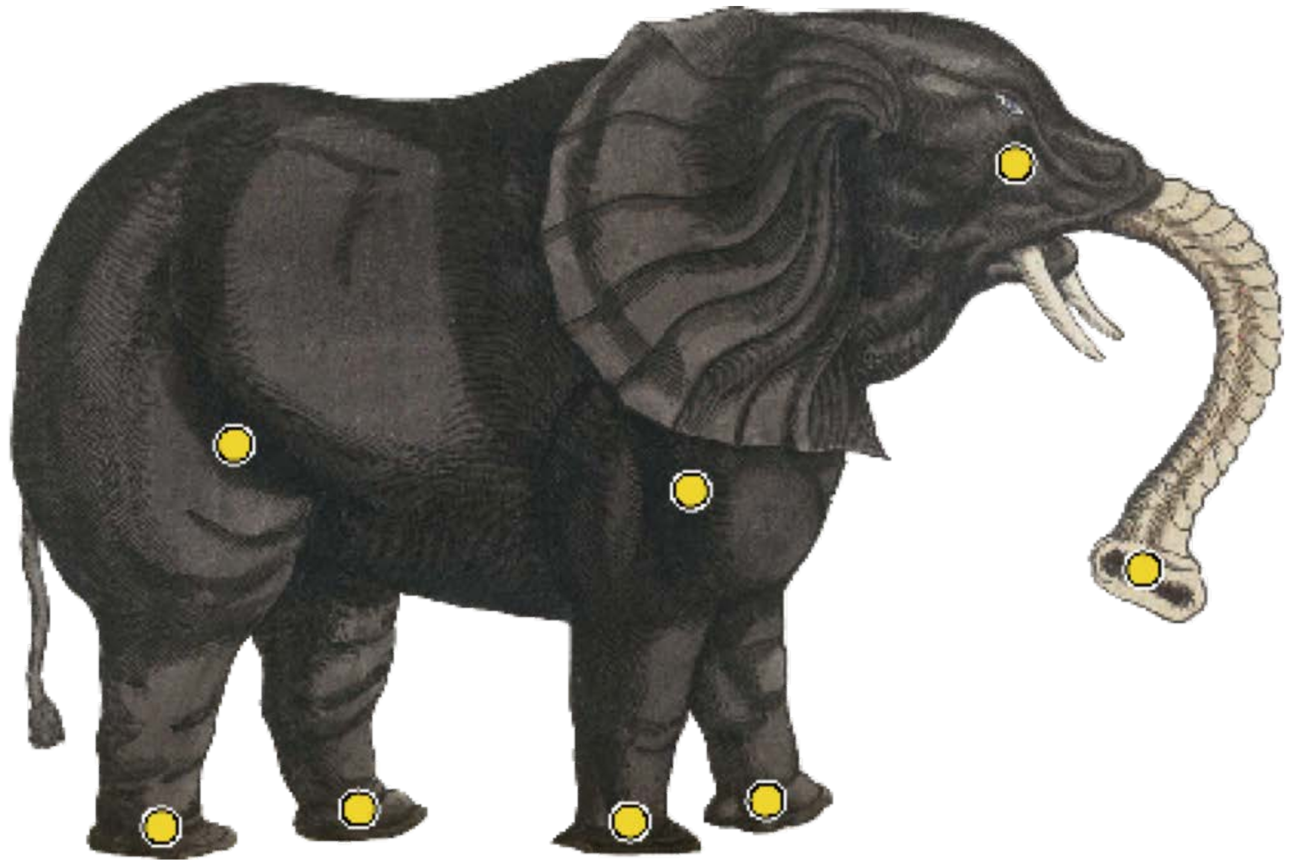
Acknowledgement: Daniele Panozzo, Alec Jacobson

LBS generalizes to different handle types

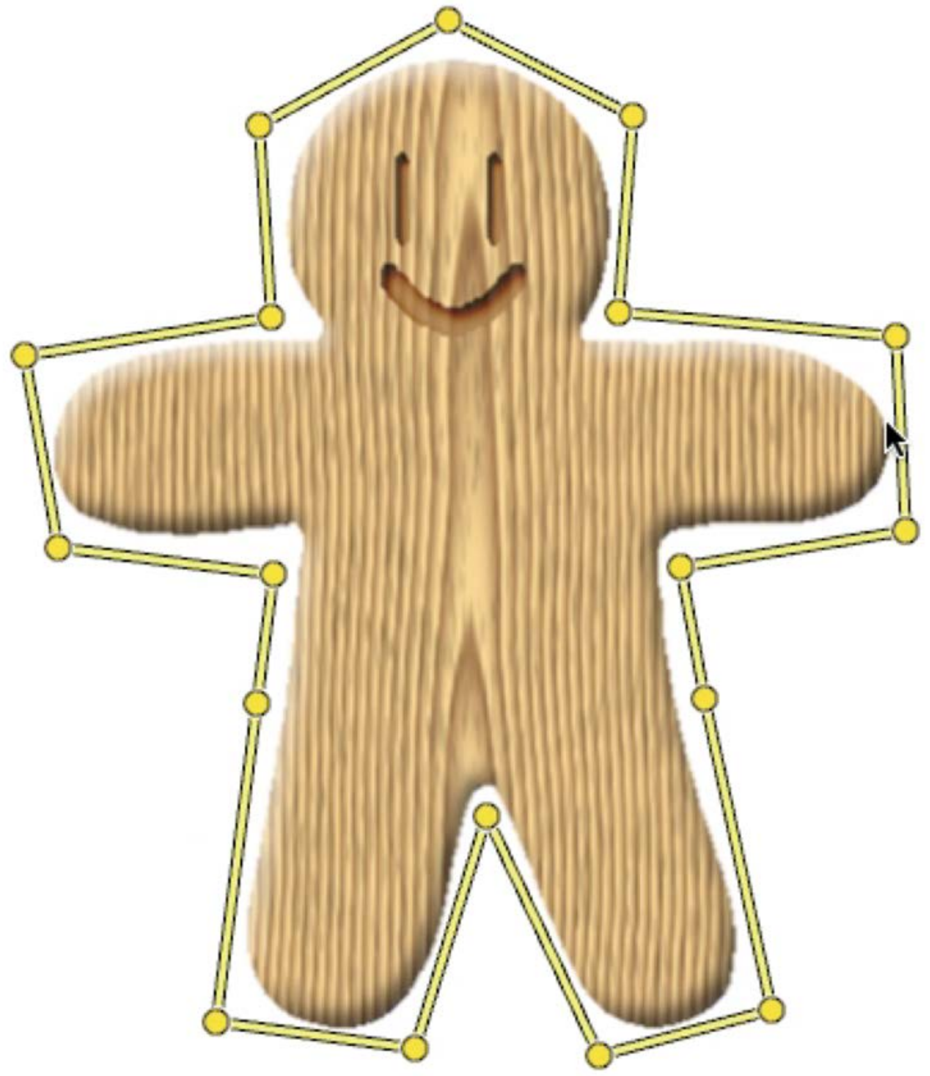


skeletons

regions

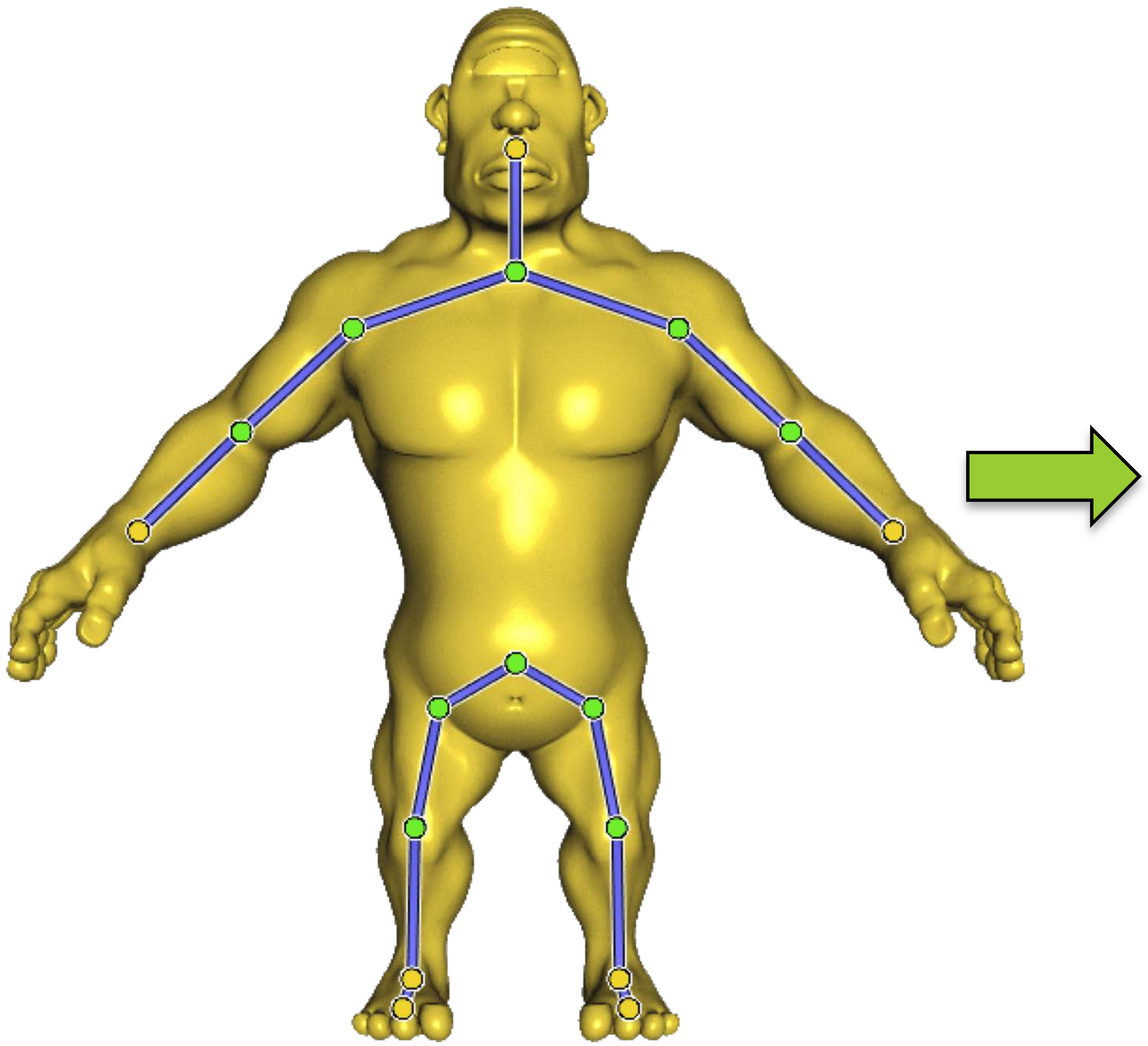


points



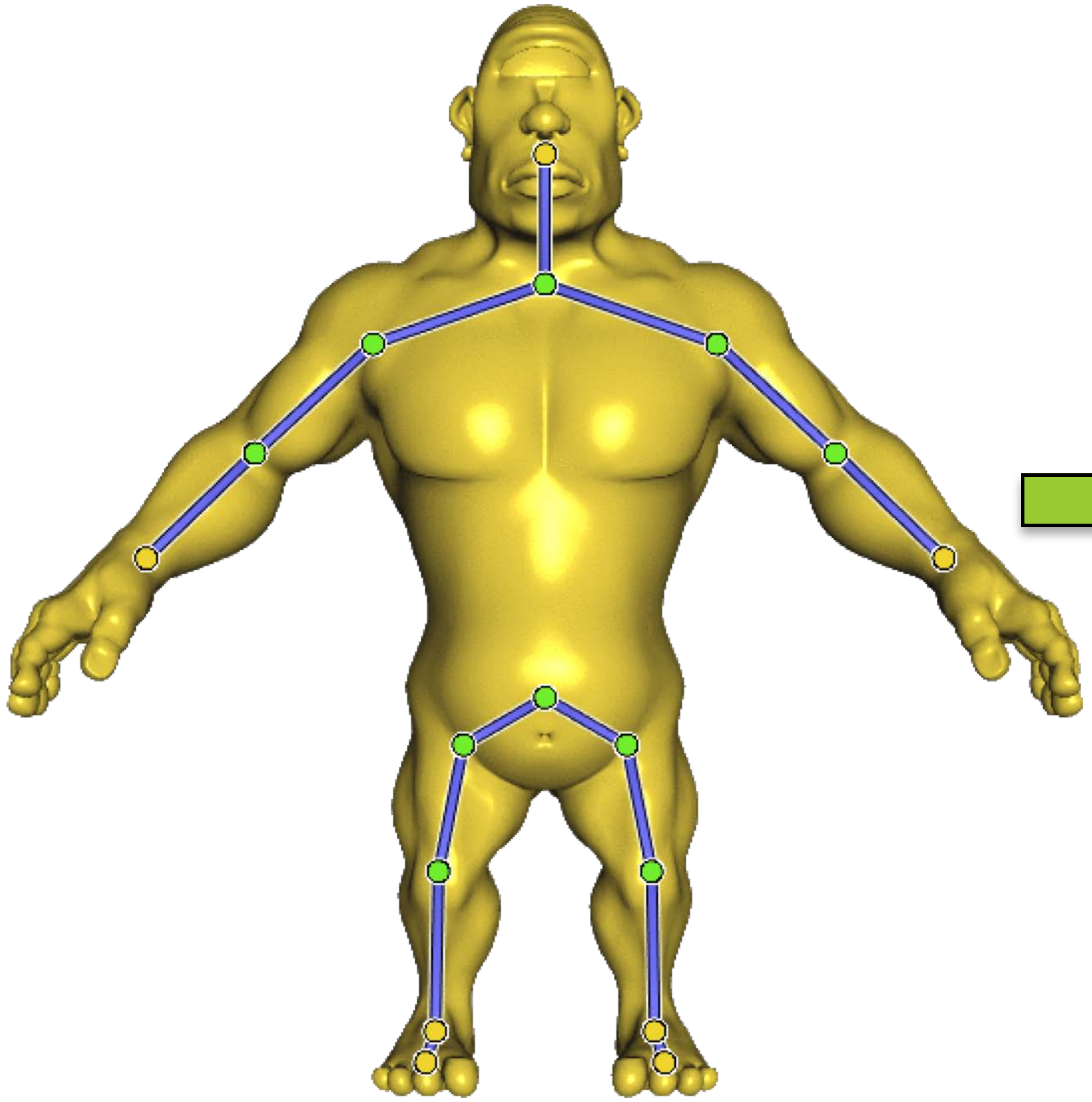
cages

Linear Blend Skinning rigging preferred for its real-time performance

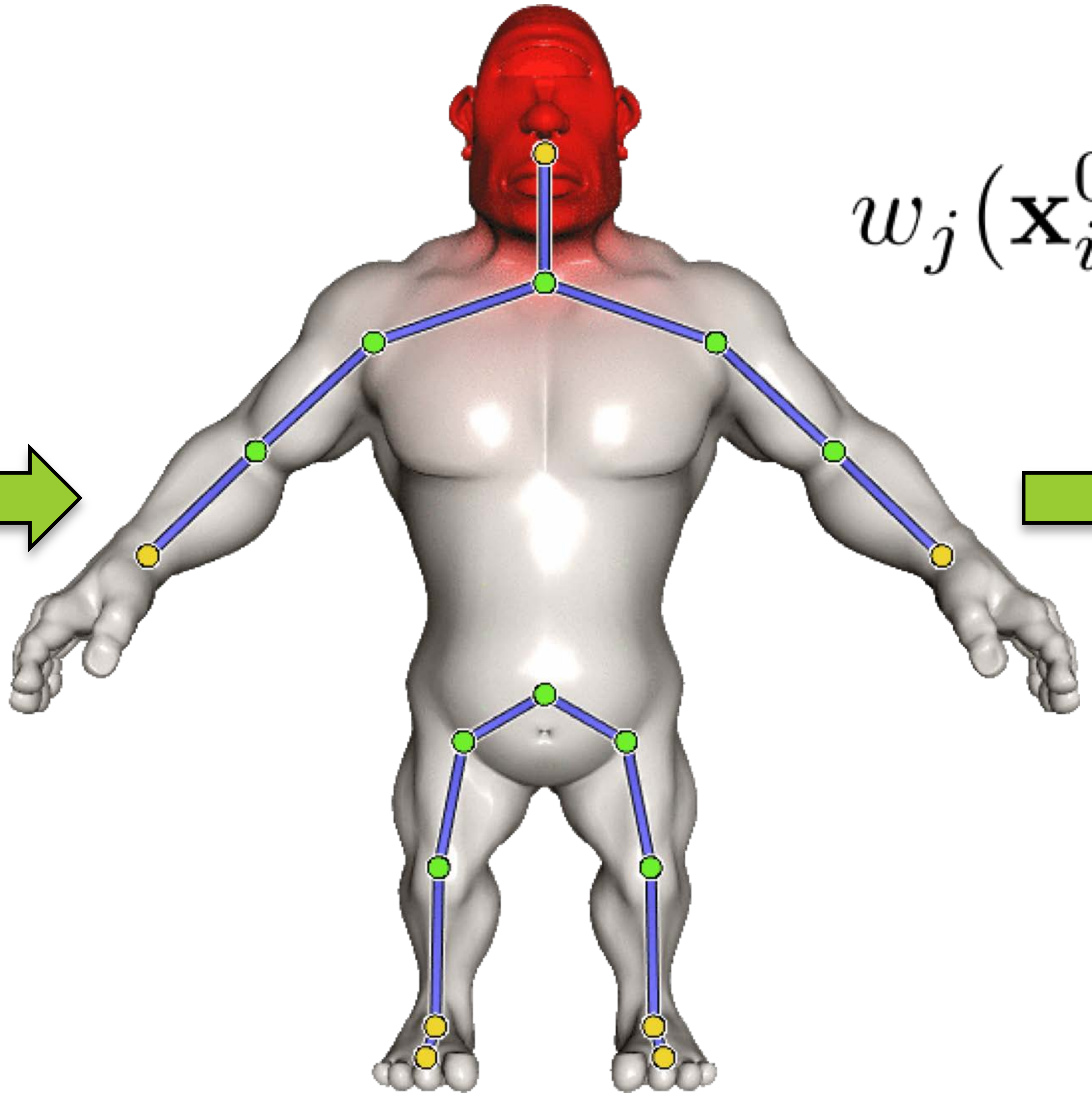


place handles in shape

Linear Blend Skinning rigging preferred for its real-time performance



place handles in shape



$w_j(\mathbf{x}_i^0)$

paint weights

Linear Blend Skinning rigging preferred for its real-time performance

place handles in shape

paint weights

deform handles

Linear Blend Skinning rigging preferred for its real-time performance

place handles in shape

paint weights

deform handles

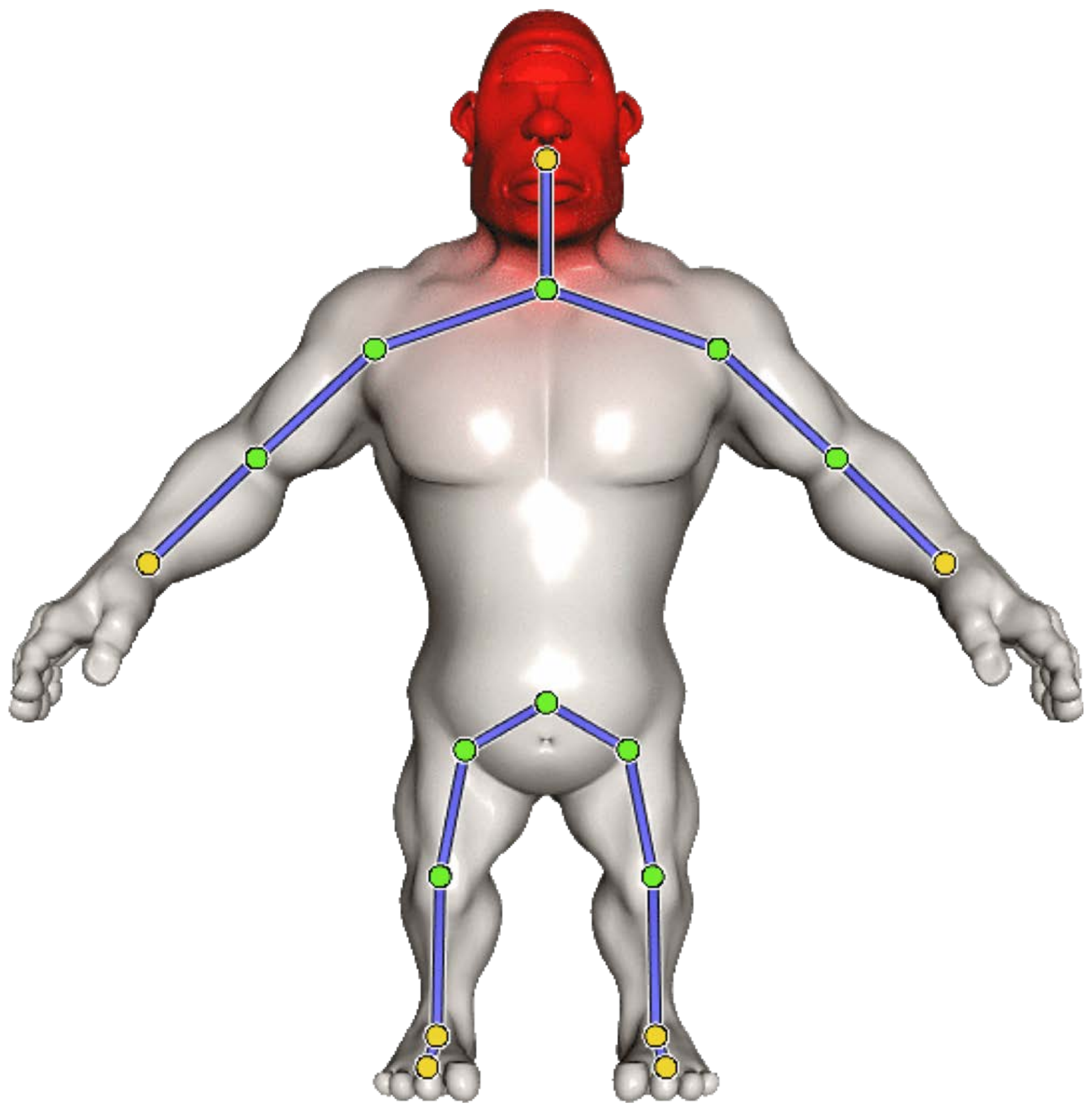
Linear Blend Skinning rigging preferred for its real-time performance

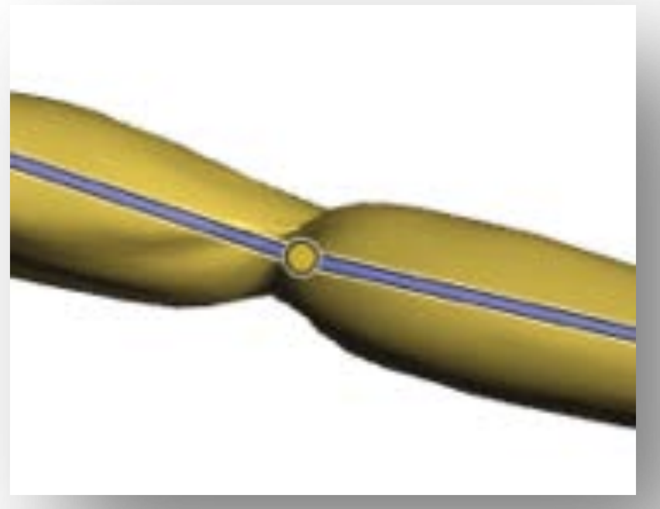
place handles in shape | paint weights | deform handles

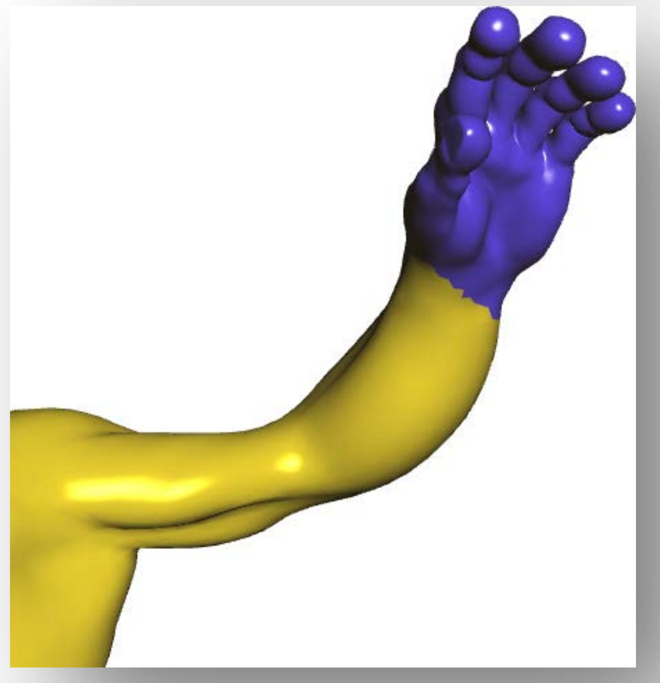
Challenges with LBS

$$\mathbf{x}_i = \sum_{j=1}^{m} \underline{w_j(\mathbf{x}_i^0)}\, \underline{\mathbf{T}_j} \begin{pmatrix} \mathbf{x}_i^0 \\ 1 \end{pmatrix}$$

- Weight functions w_j
  - Can be manually painted or automatically generated
- Degrees of freedom $\mathbf{T}_j$
  - Exposed to the user (possibly with a kinematic chain)
- Richness of achievable deformations
  - Want to avoid common pitfalls – candy wrapper, collapses







Properties of the Weights

$$\sum_{j \in H} w_j(\mathbf{x}^0) = 1$$

Partition of unity

Handle vertices

$$w_j \Big|_{H_k} = \delta_{jk}$$

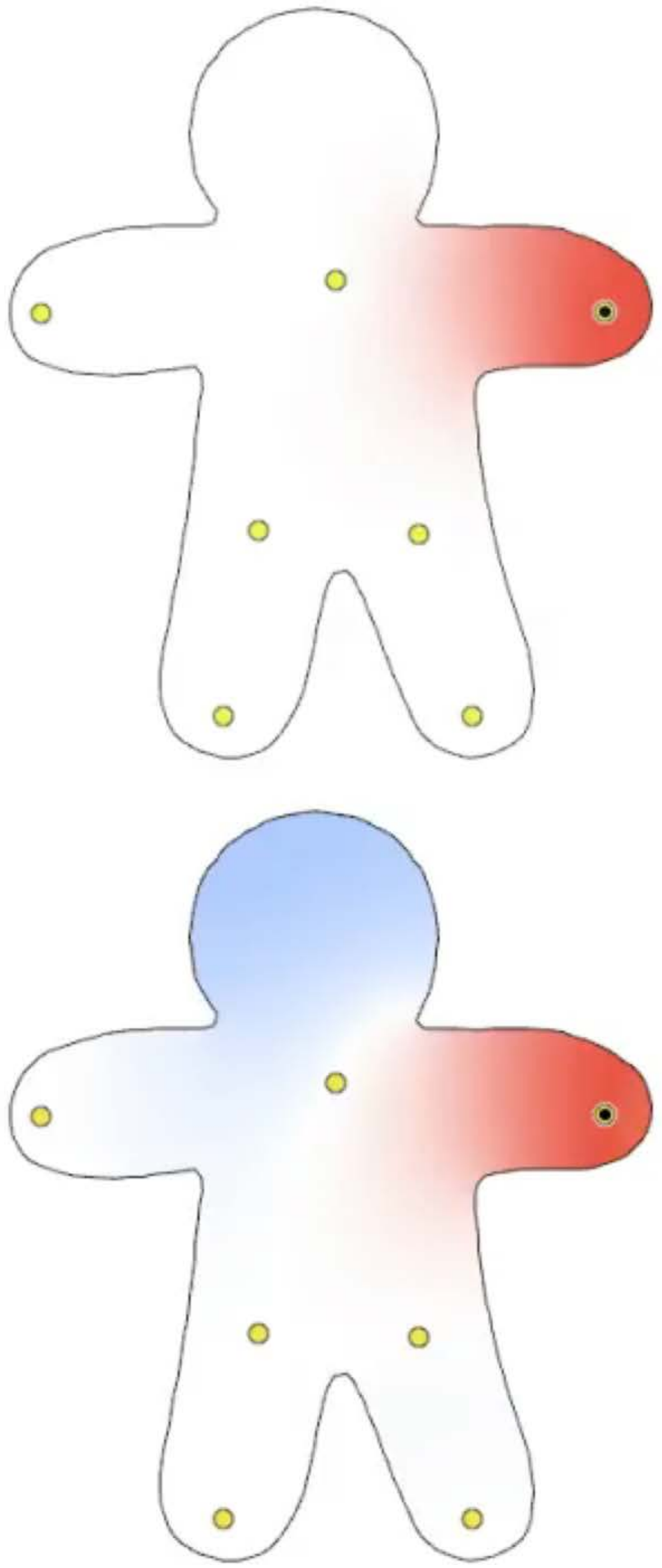
w_j is linear along cage faces

Interpolation of handles

Weights Should Be Positive

Bounded Biharmonic Weights
[Jacobson et al. 2011]

Unconstrained biharmonic
[Botsch and Kobbelt 2004]

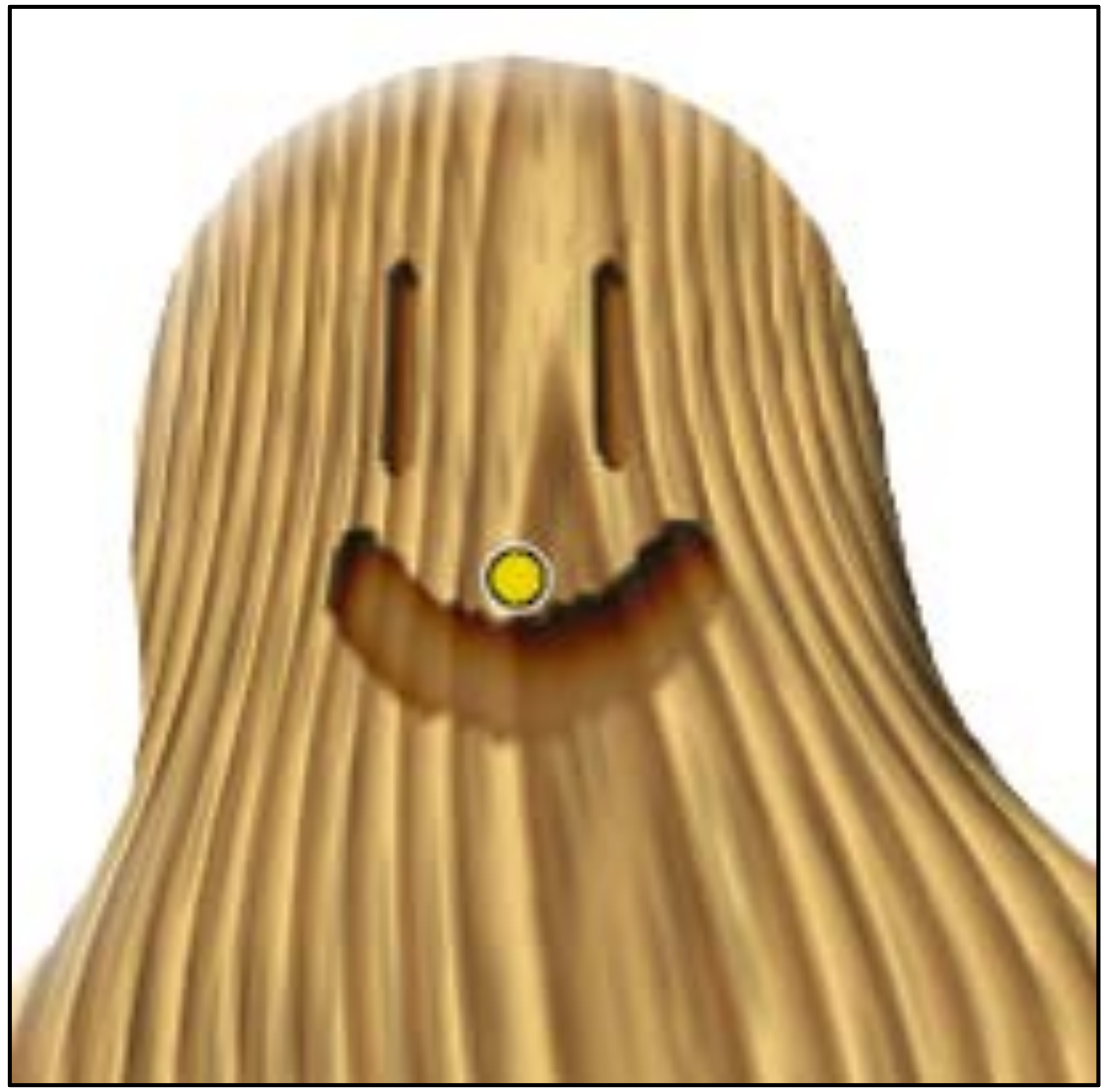


Weights Should Be Smooth

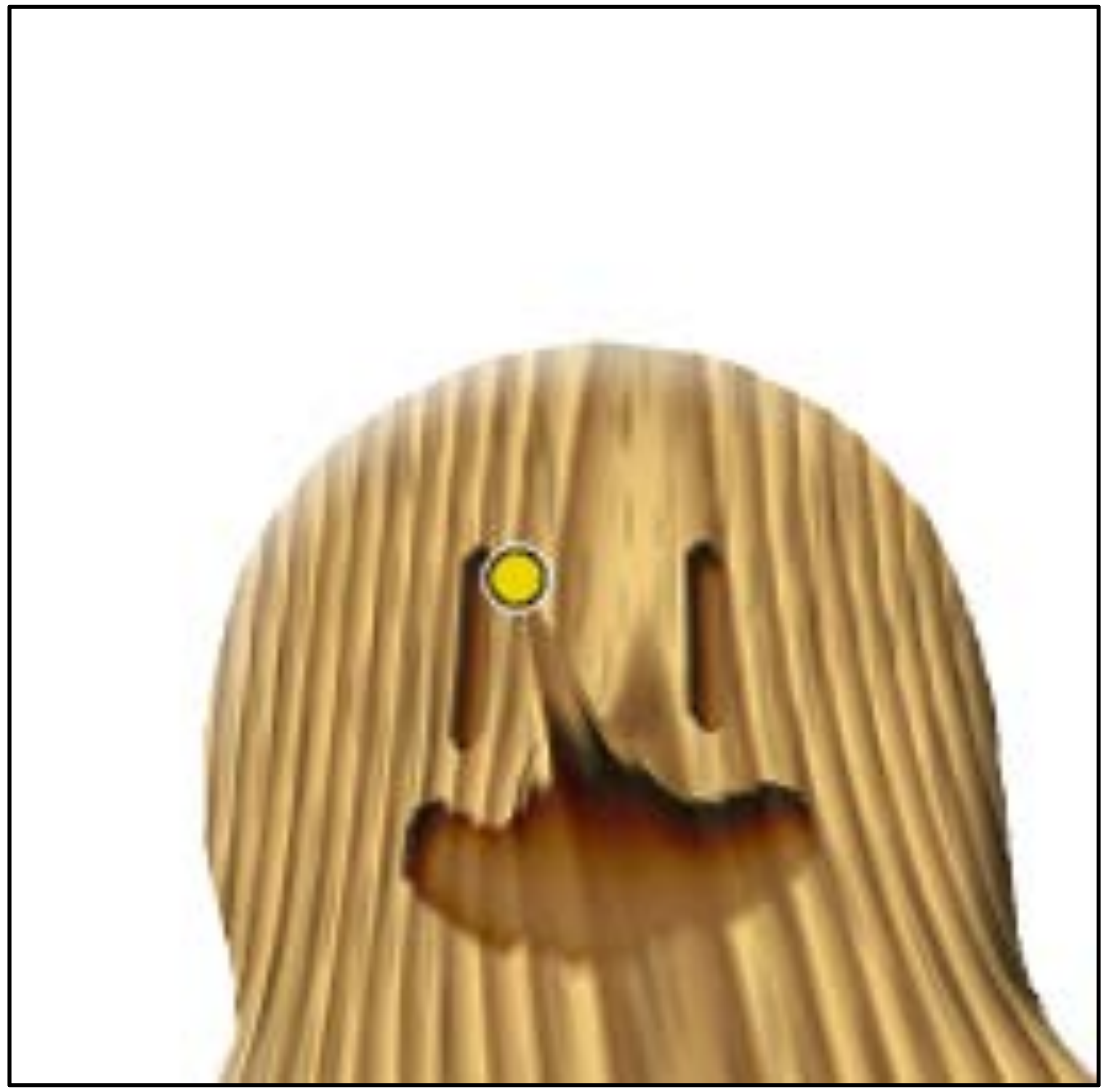
Bounded Biharmonic Weights [Jacobson et al. 2011]

Extension of Harmonic Coordinates [Joshi et al. 2005]

Weights Should Be Smooth

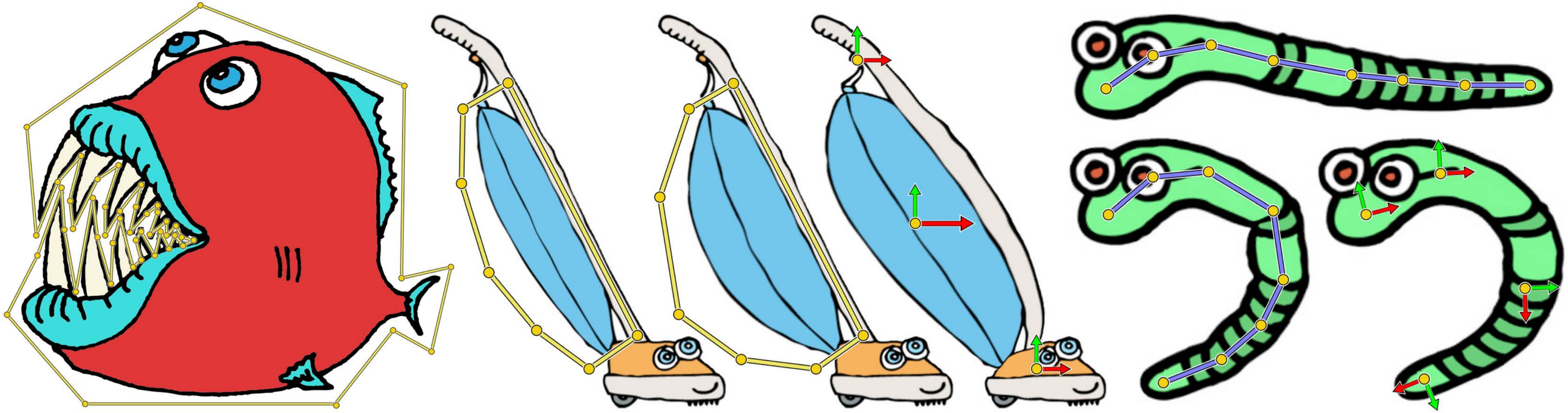


Bounded Biharmonic Weights



Extension of Harmonic Coordinates
[Joshi et al. 2005]

Different Types of Handles



Bounded biharmonic weights enforce properties as constraints to minimization

$$\underset{w_j}{\arg\min} \; \frac{1}{2}\int_{\Omega} |\Delta w_j|^2 dV$$

$$w_j\Big|_{H_k} = \delta_{jk}$$

w_j is linear along cage faces

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Constant inequality constraints

$$0 \le w_j(\mathbf{x}^0) \le 1$$

Partition of unity

$$\sum_{j \in H} w_j(\mathbf{x}^0) = 1$$

Bounded biharmonic weights enforce properties as constraints to minimization

$$\arg\min_{w_j} \frac{1}{2}\int_\Omega |\Delta w_j|^2 dV$$

$$w_j\Big|_{H_k} = \delta_{jk}$$

w_j is linear along cage faces

Constant inequality constraints

$$0 \leq w_j(\mathbf{x}^0) \leq 1$$

Solve independently and normalize

$$w_j(\mathbf{x}^0) = \frac{w_j(\mathbf{x}^0)}{\sum_{i\in H} w_i(\mathbf{x}^0)}$$

Bounded biharmonic weights enforce properties as constraints to minimization

$$\sum_{j=1}^{m} \frac{1}{2} \int_{\Omega} \|\Delta w_j\|^2 dV \quad \approx \quad \sum_{j=1}^{m} \frac{1}{2} (M^{-1} L \mathbf{w}_j)^T M (M^{-1} L \mathbf{w}_j)$$

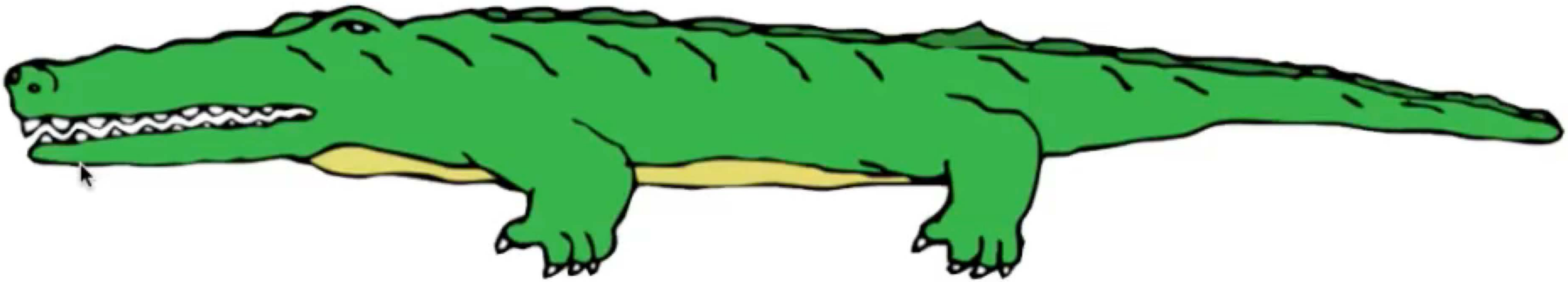
Bounded biharmonic weights enforce properties as constraints to minimization

$$\sum_{j=1}^{m} \frac{1}{2} \int_{\Omega} \|\Delta w_j\|^2 dV \approx \sum_{j=1}^{m} \frac{1}{2} (M^{-1} L \mathbf{w}_j)^T M (M^{-1} L \mathbf{w}_j)$$

$$= \frac{1}{2} \sum_{j=1}^{m} \mathbf{w}_j^T \left(L M^{-1} L\right) \mathbf{w}_j$$

Bounded biharmonic weights enforce properties as constraints to minimization

Some examples of LBS in action



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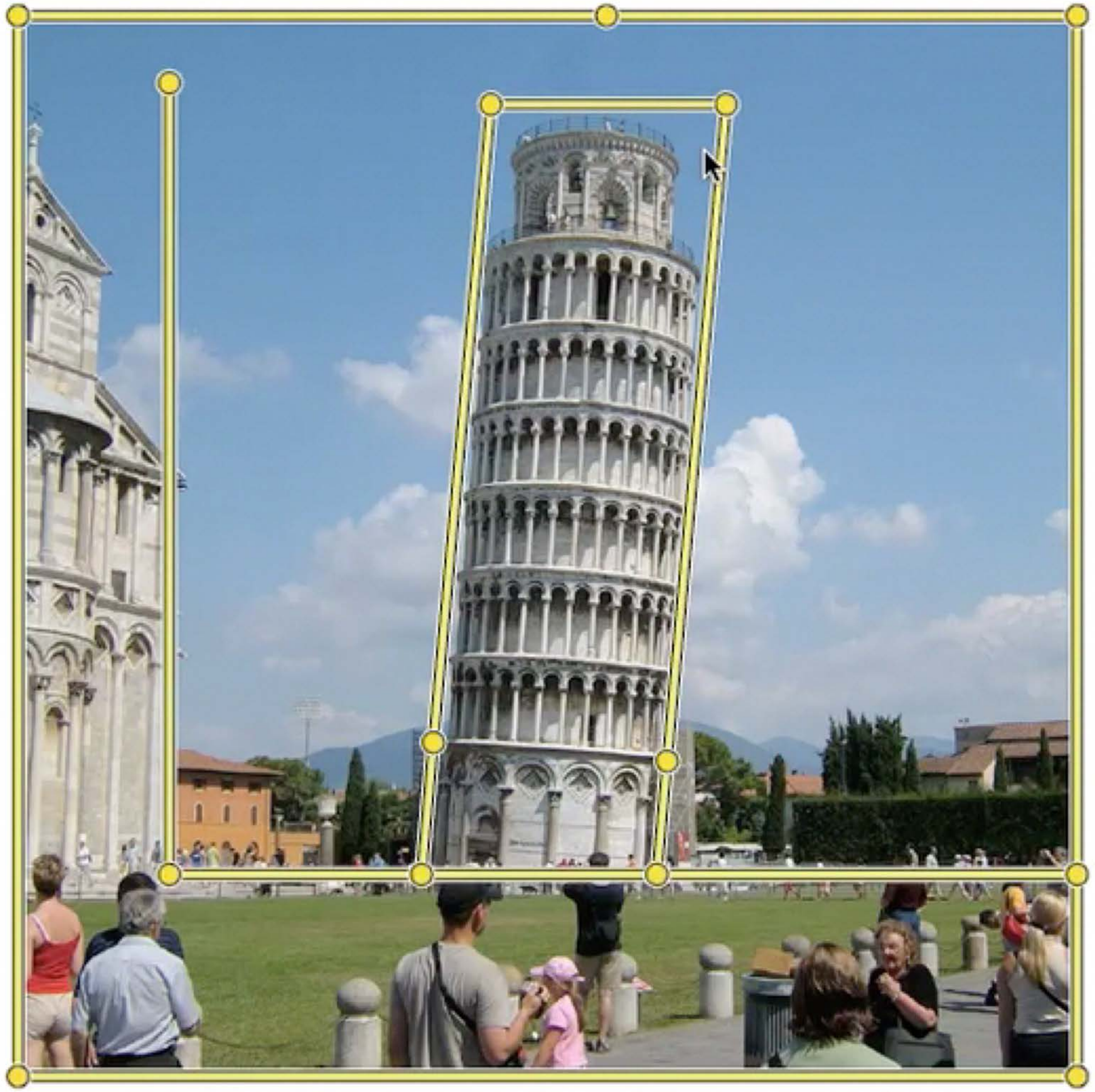

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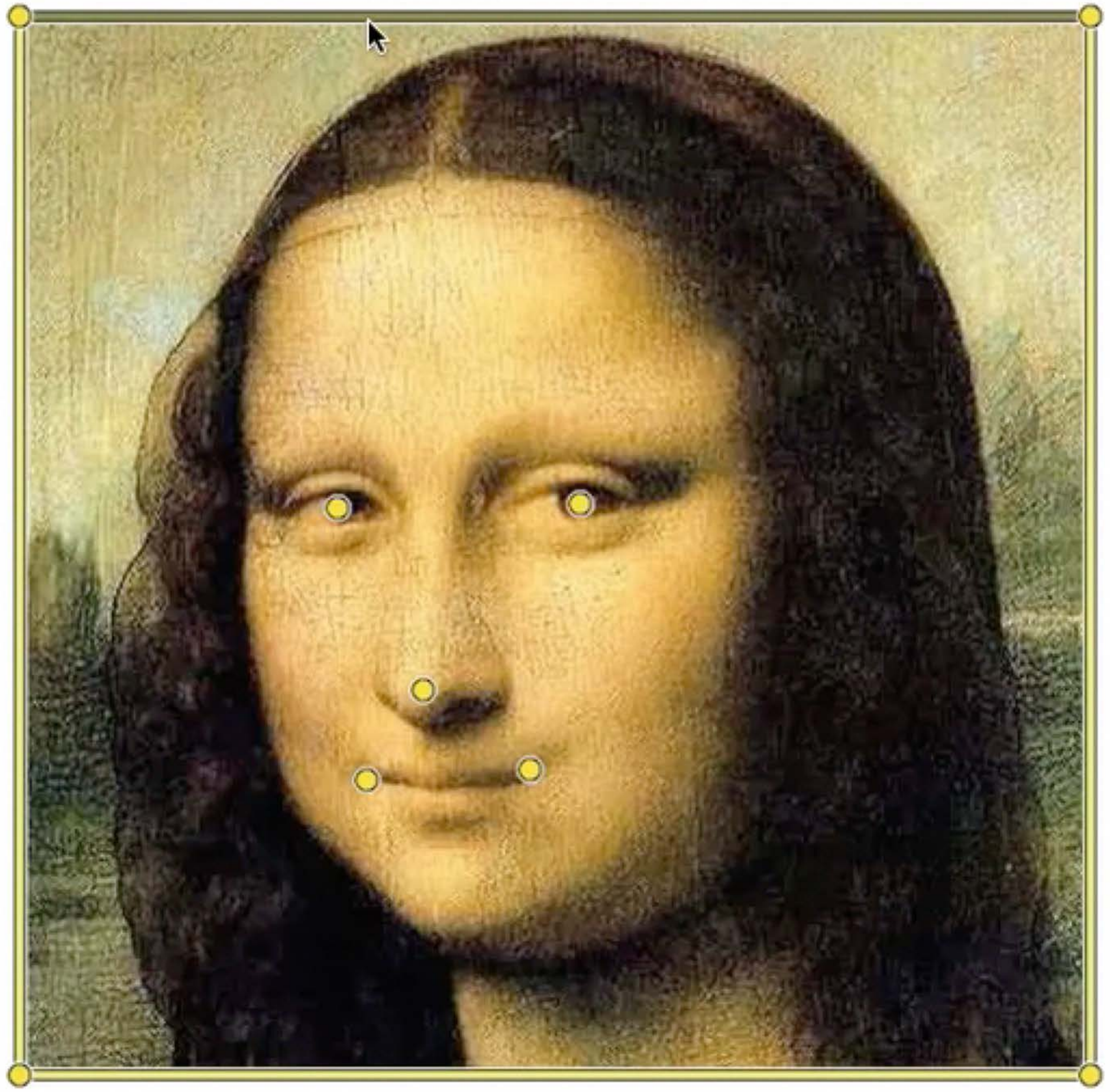
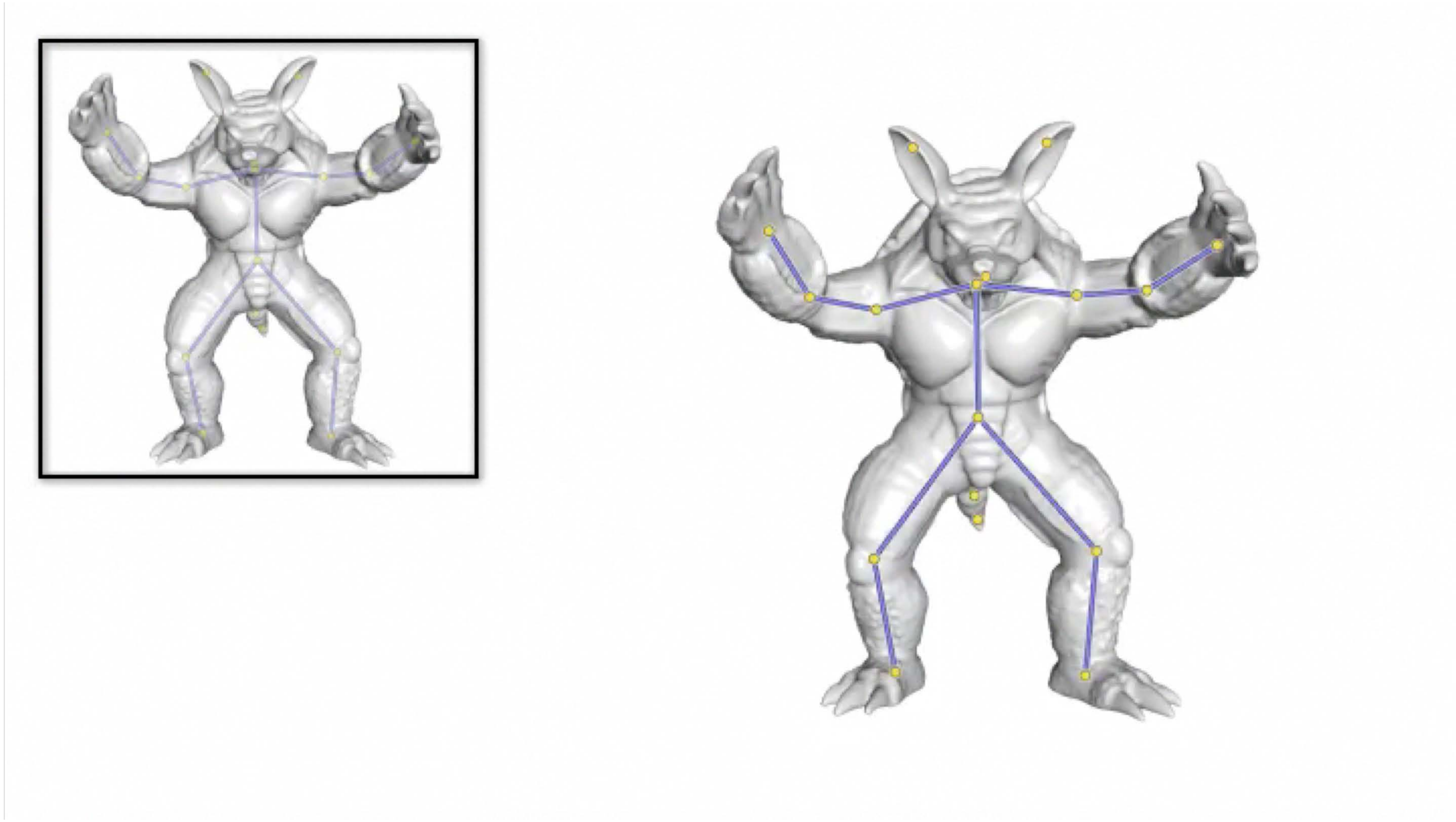
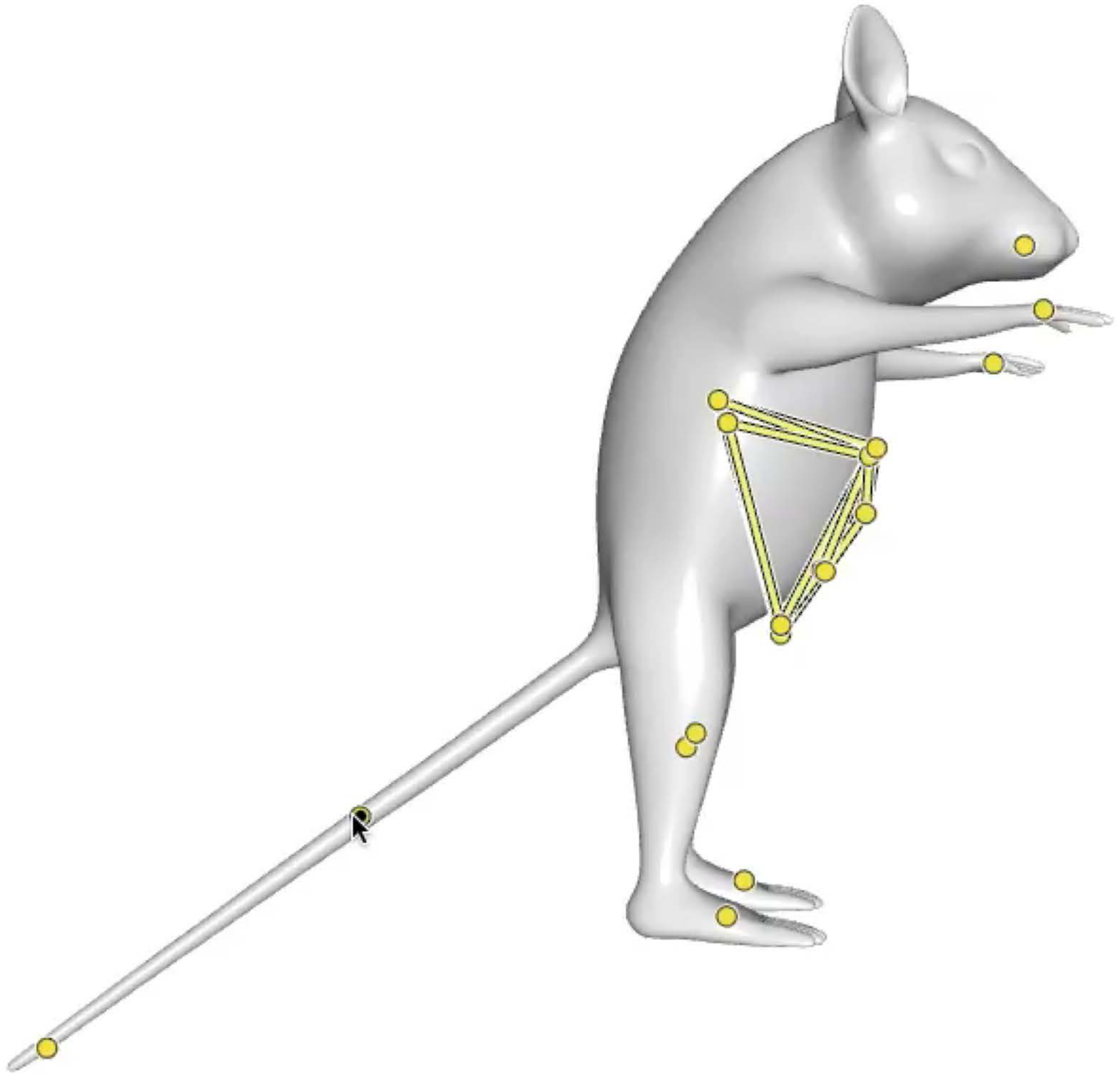


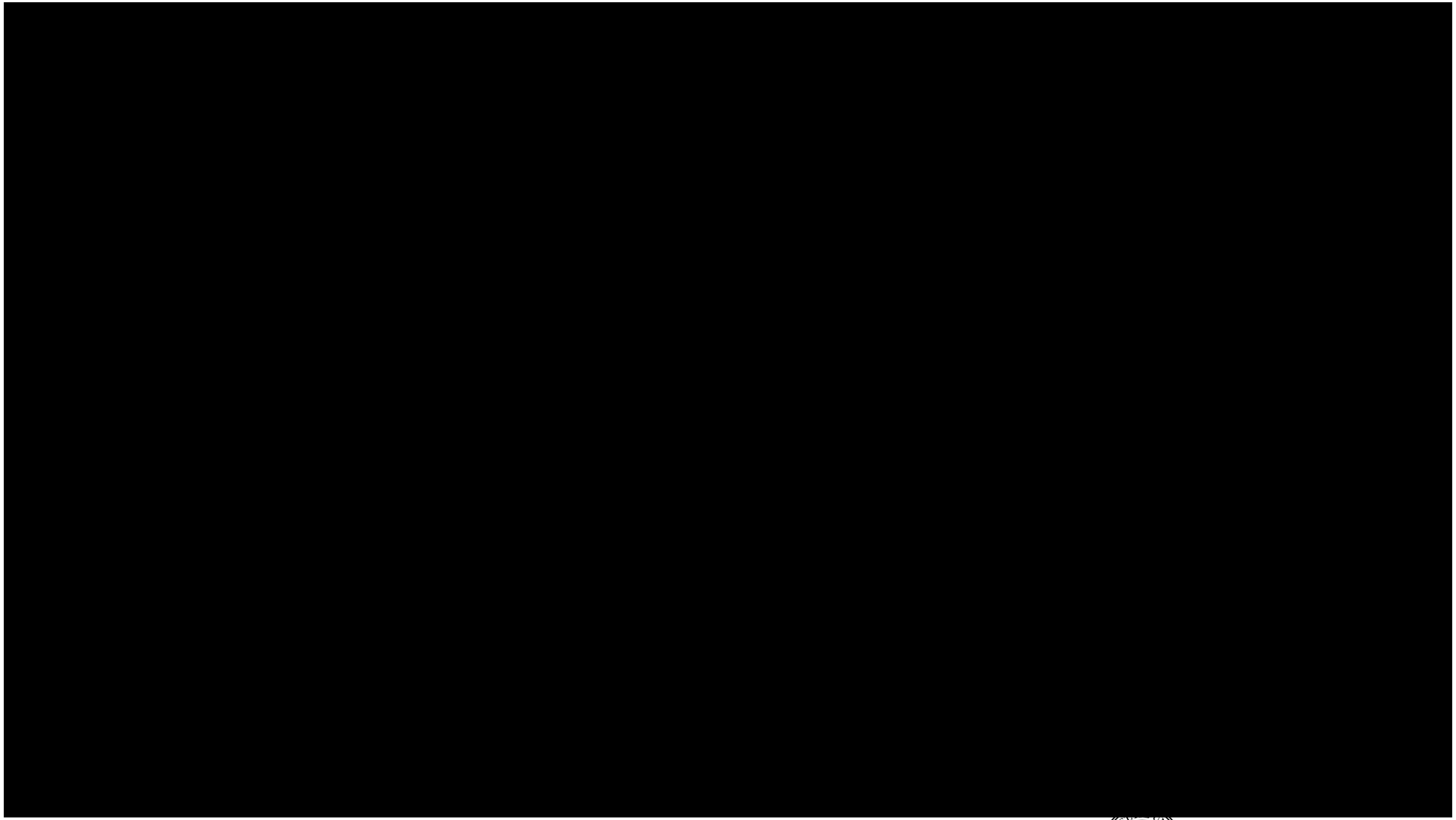
3D Characters



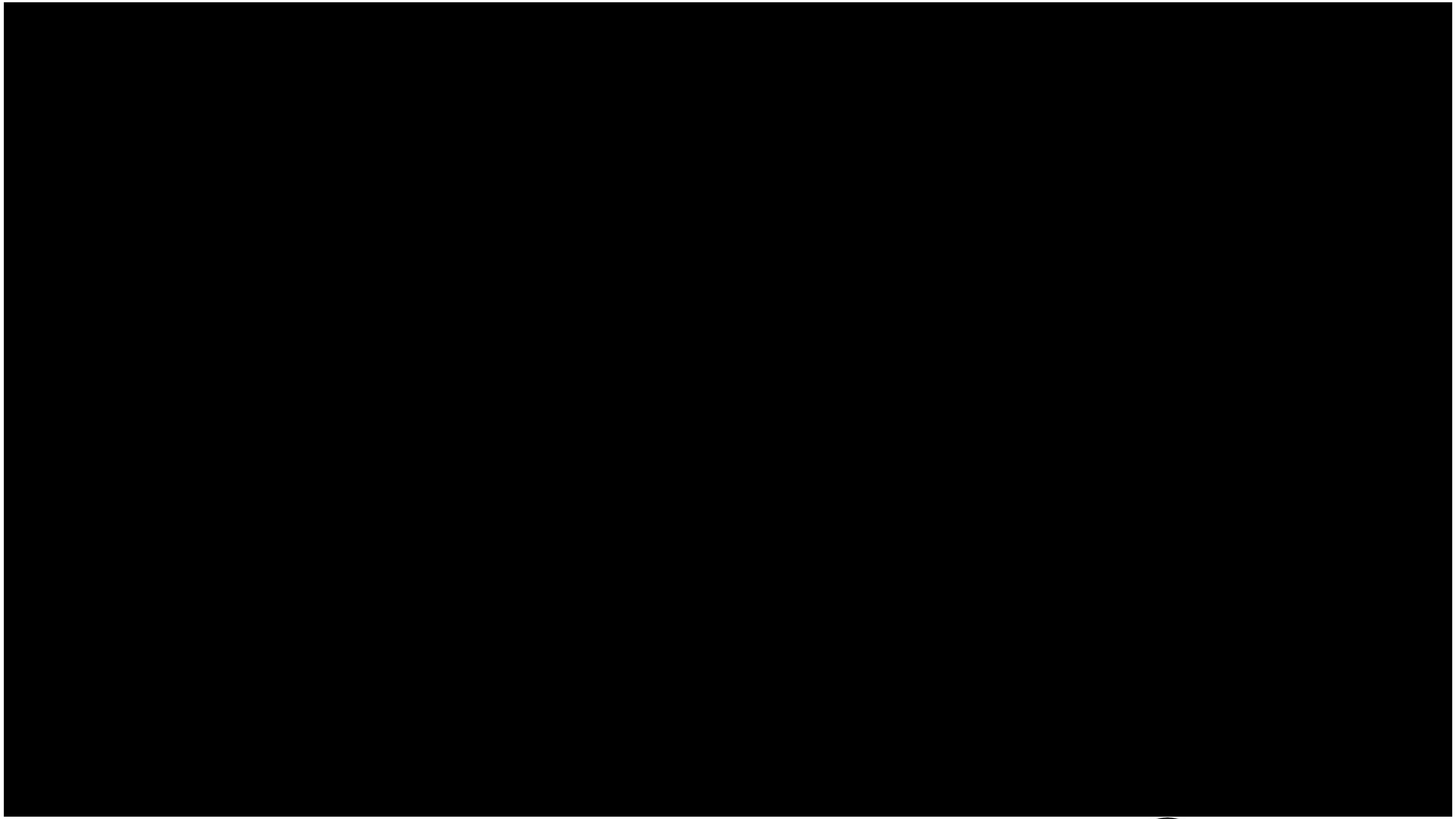
Mixing different handle types



Skinning Decomposition for Rigid Bones



Skinning Decomposition for Skeletons



References

Fundamentals of Computer Graphics, Fourth Edition
4th Edition **by [Steve Marschner](), [Peter Shirley]()**
Chapter 16

Skinning: Real-time Shape Deformation
ACM SIGGRAPH 2014 Course
http://skinning.org