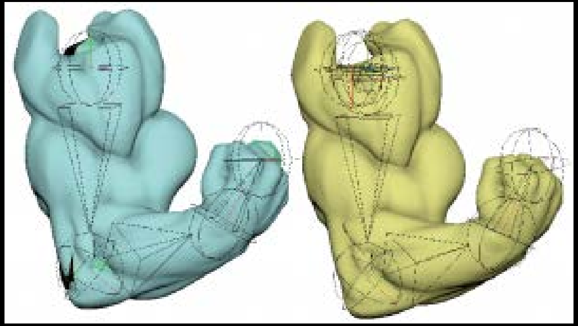
Sampling-based Rig Conversion into Non-rigid Helper Bones



Tomohiko Mukai*, Tokai University
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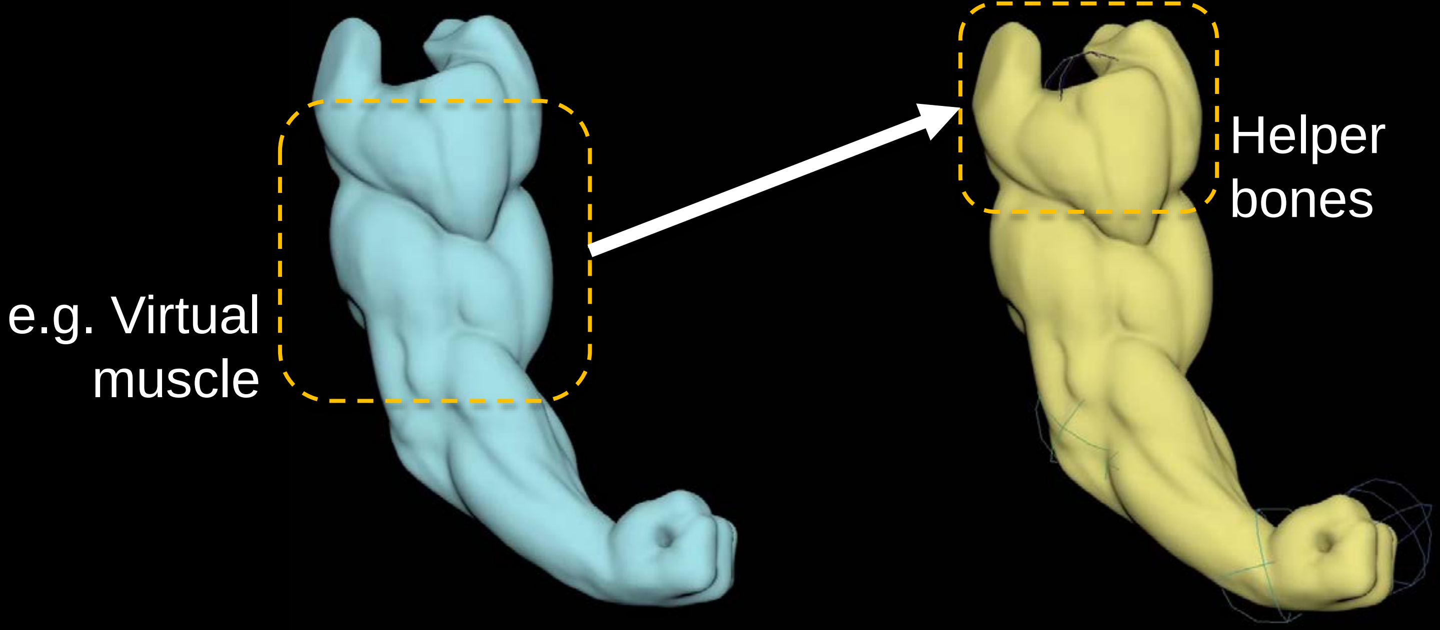
Motivation

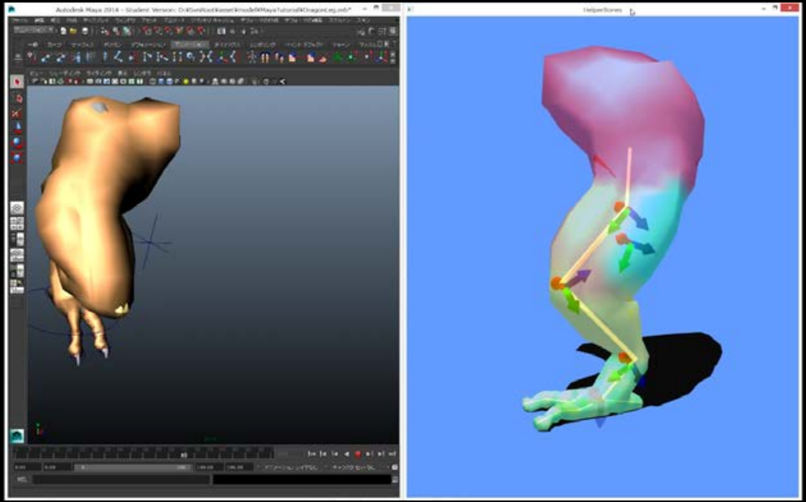
Heavyweight, skeleton-driven skin deformer ➡ Linear blend skinning (LBS)-based helper bone rig



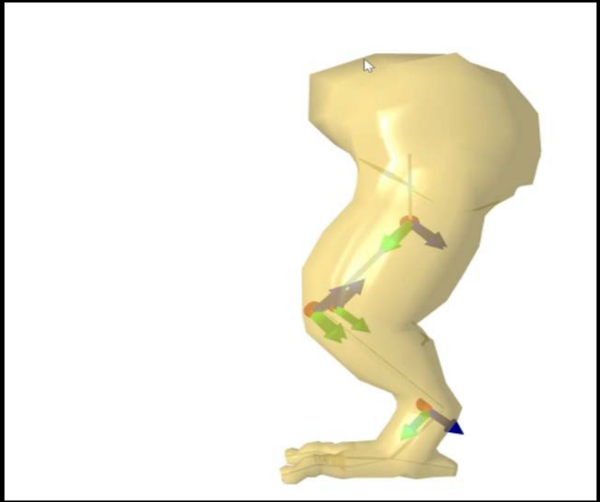
Rigging with Rigid Helper Bones

[I3D 2015, SIG 2016]

Linear blend skinning + Procedural control of rigid bones



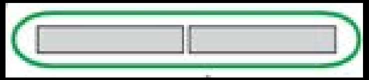
Data-driven rigging [I3D 2015]



+ dynamics [SIG 2016]

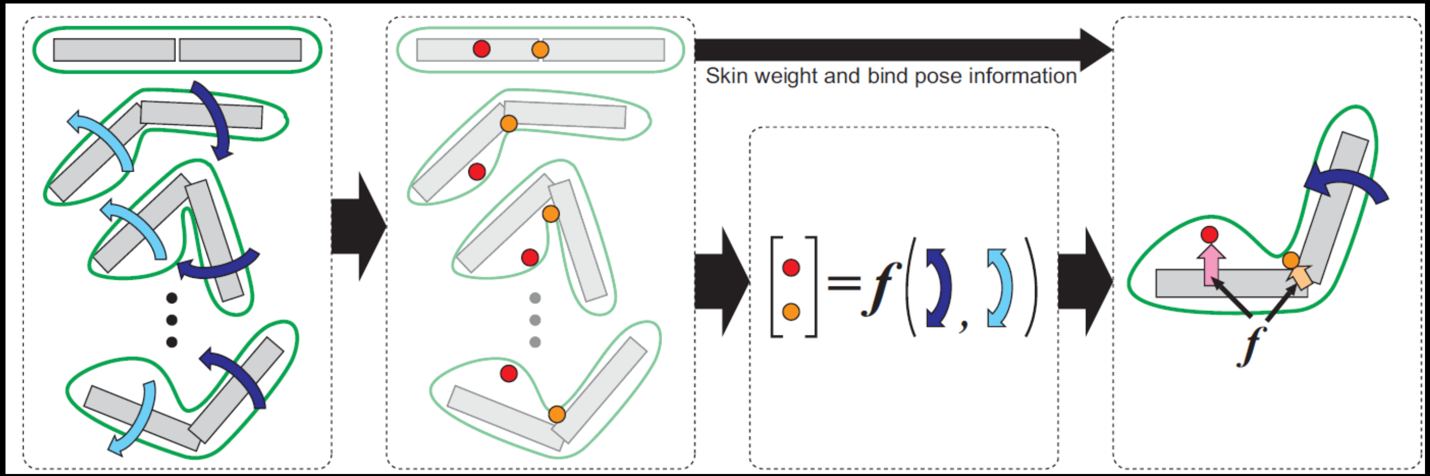
Our approach: adding scaling component to helper bones

Data-driven Rigging [I3D 2015]



Source model

How to sample?



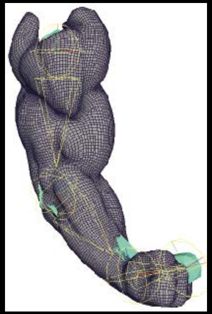
Training data

Bone trans–formation

Bone controller

Helper bone rig

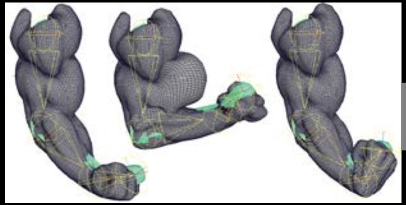
Overview



Source rig
(skeleton-driven
deformer)

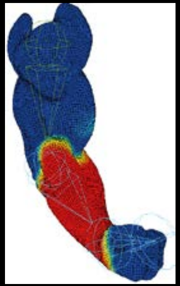
Two-step sampling

Geometric criteria



Training shapes

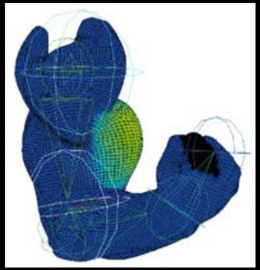
Data-driven skinning



LBS rig with no helper

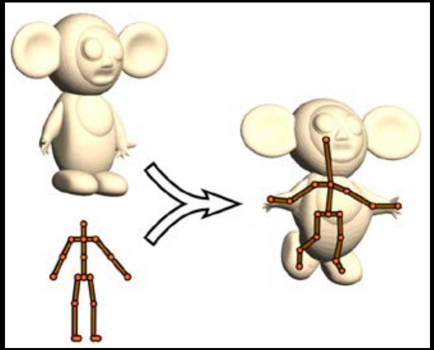
Non-rigid helper bone rigging

Rigid transformation + scaling component

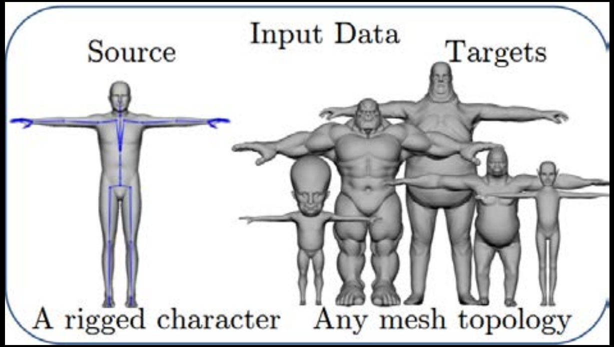


Non-rigid helper bones

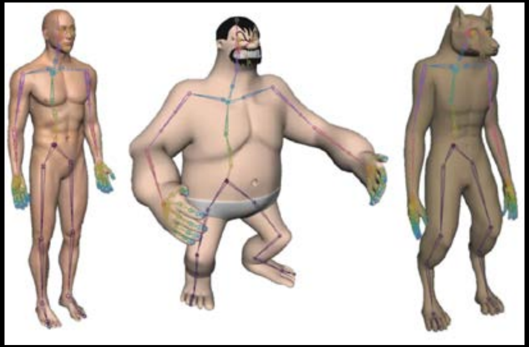
Related Work



Automated rigging
[Baran 2007]



Animation setup transfer
[Avril 2016]



Anatomy Transfer
[Ali-Hamadi 2013]

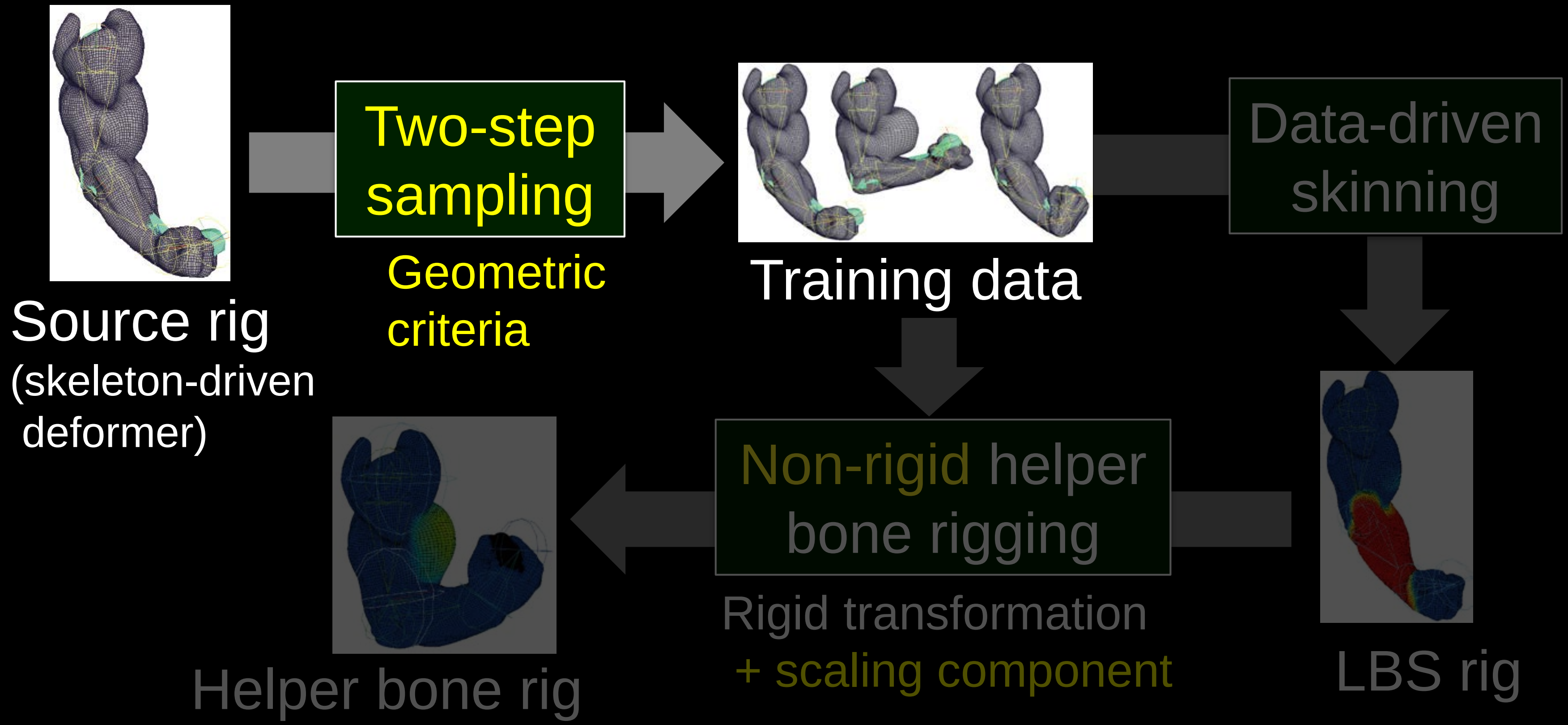
Our approach: Skeleton-based deformer into helper bones,
Same skeleton structure, Same skin mesh geometry

Related Commercial Tools

- Autodesk Maya
  - Bake Deformer Tools
- SideFx Houdini
  - Skinning Converter

Our approach: Higher conversion quality using helper bones, and sampling mechanism

Overview

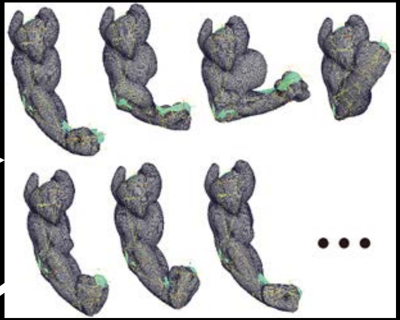

Two-step sampling
Geometric criteria
Training data
Data-driven skinning
Source rig
(skeleton-driven deformer)
Non-rigid helper bone rigging
Rigid transformation + scaling component
LBS rig
Helper bone rig

Two-step Sampling of Training Data

Source rig
(blackbox)

Per-joint uniform sampling

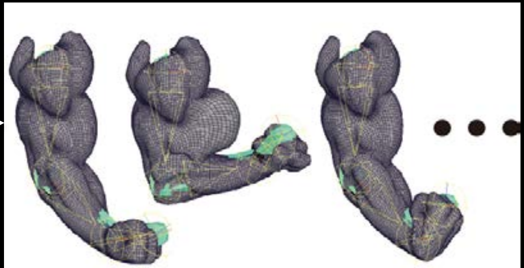
to cover possible poses



Shape samples

Pose selection

through deformation influence analysis



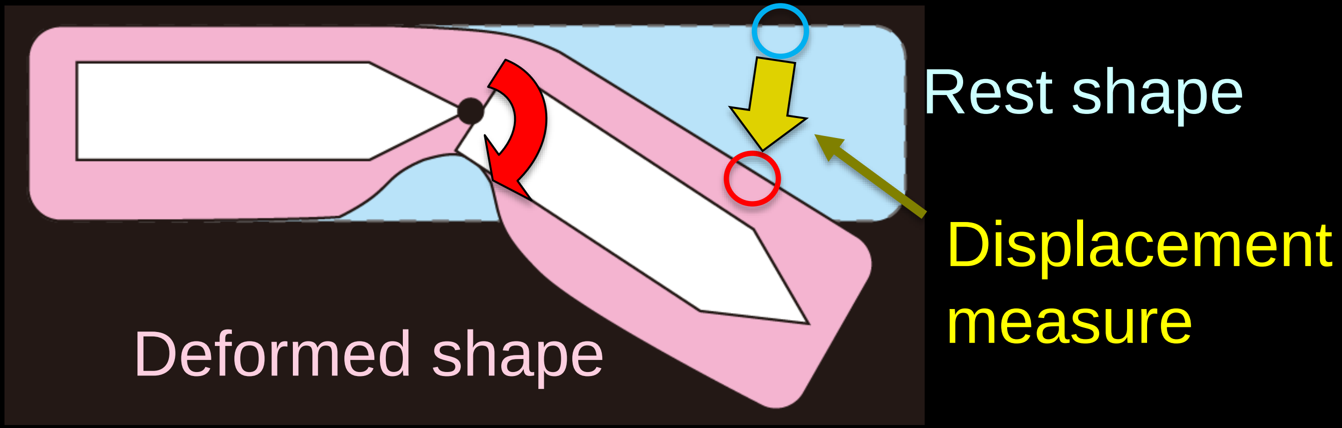
Selected samples

Per-joint Uniform Sampling

- Uniform 3D rotation sampling [Yershova 2010] within joint range of motion
- Per-joint sampling while fixing other joints
  - # of samples $\propto$ # of joints
  - Approximated solution for LBS

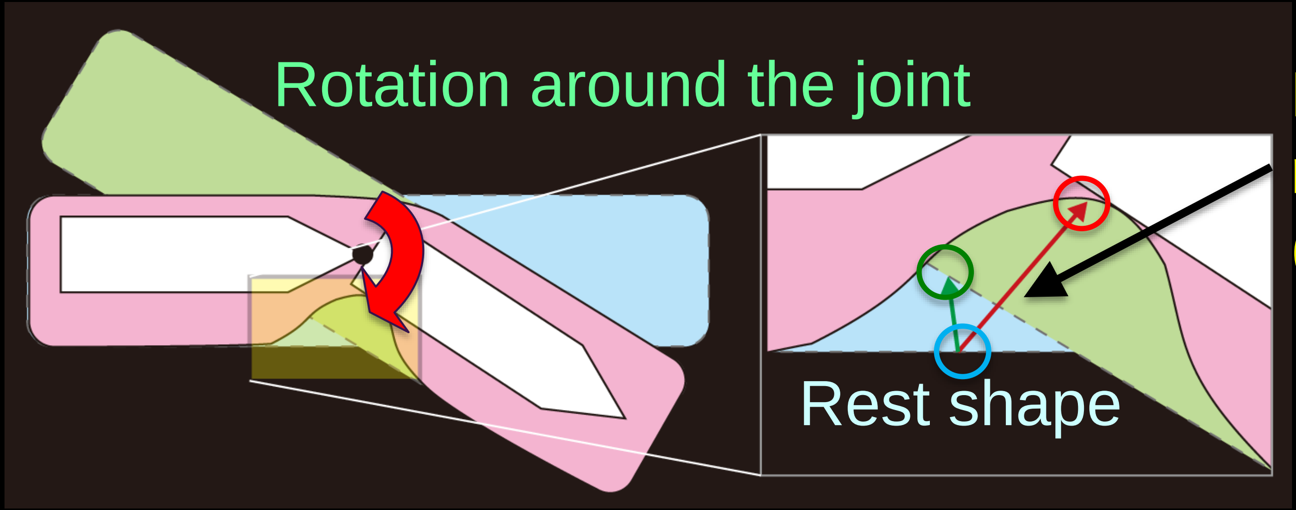
Displacement Measure

– quantifies the size of the displacement that the joint rotation yields on the vertex



Dependency Measure

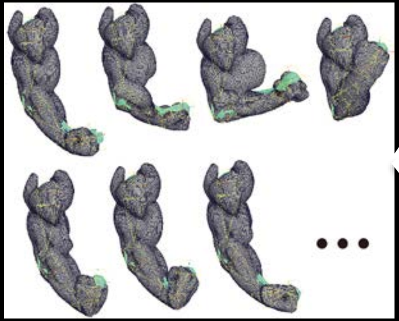
– quantifies the influence of the joint rotation on the vertex displacement ($\propto$ skinning weight)



Dependency measure (inner product)

Deformed shape

Pose Selection



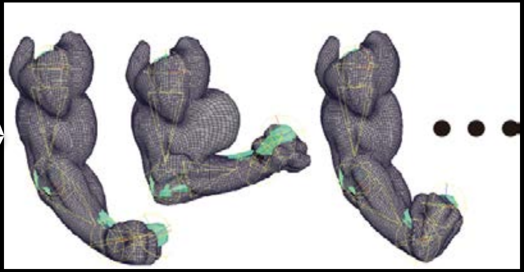
(# of joints) × 200 samples

Displacement measure

Important for approximating visible non-rigid deformation
(ex. exaggerated deformation)

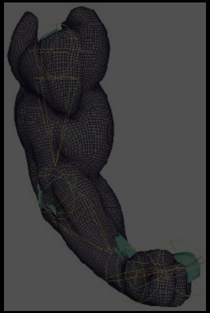
Dependency measure

Important for accurate skinning weight estimation



(# of joints) × 20 samples

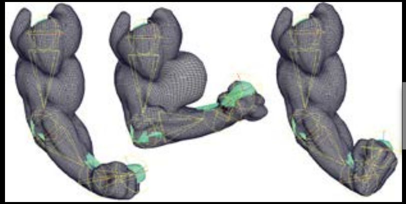
Data-driven Weight Optimization



Source rig
(skeleton-driven
deformer)

Two-step sampling

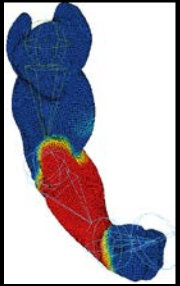
Geometric criteria



Training data

Data-driven skinning

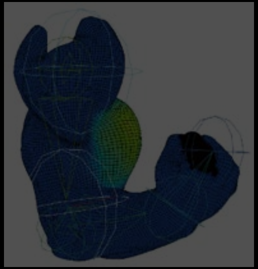
[Le 2012]



LBS rig with no helper

Non-rigid helper bone rigging

Rigid transformation
+ scaling component



Helper bone rig

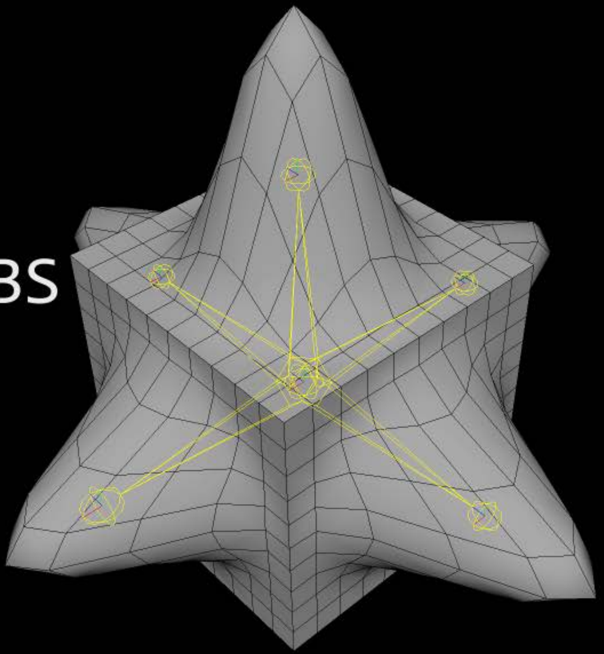
Experiments

Linear blend skinning(LBS) to LBS

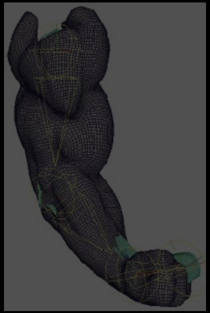
Branched skeleton

602 vertices

Six joints



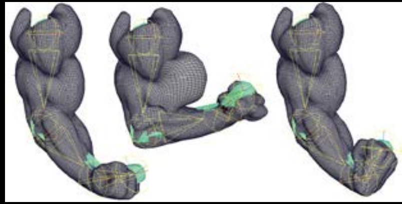
Helper Bone Rigging



Source rig
(skeleton-driven deformer)

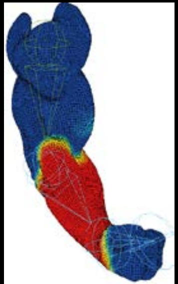
Two-step sampling

Geometric criteria



Training data

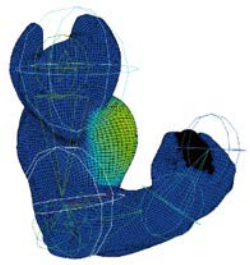
Data-driven skinning



LBS rig with no helper

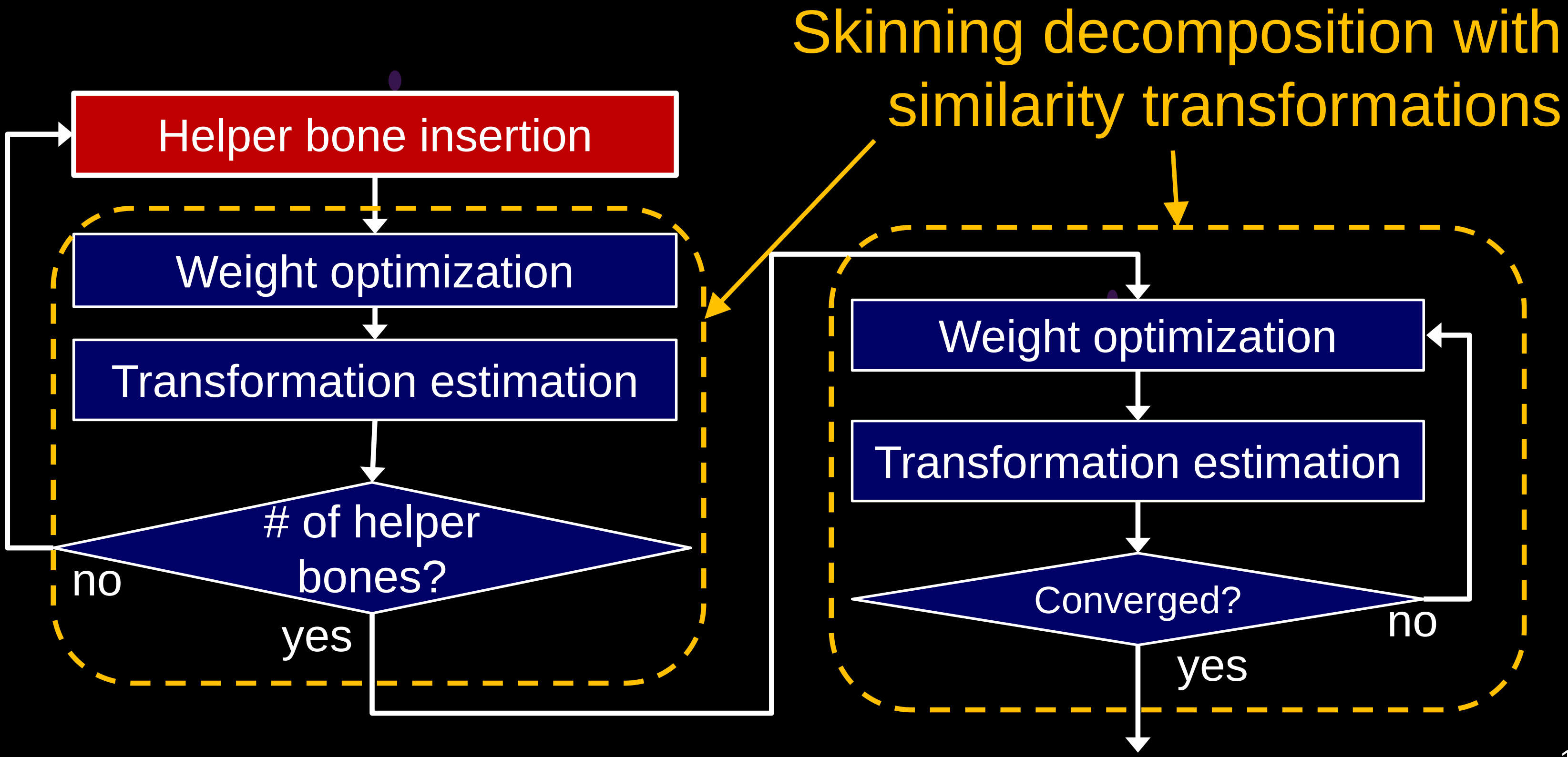
Non-rigid helper bone rigging

Rigid transformation
+ scaling component



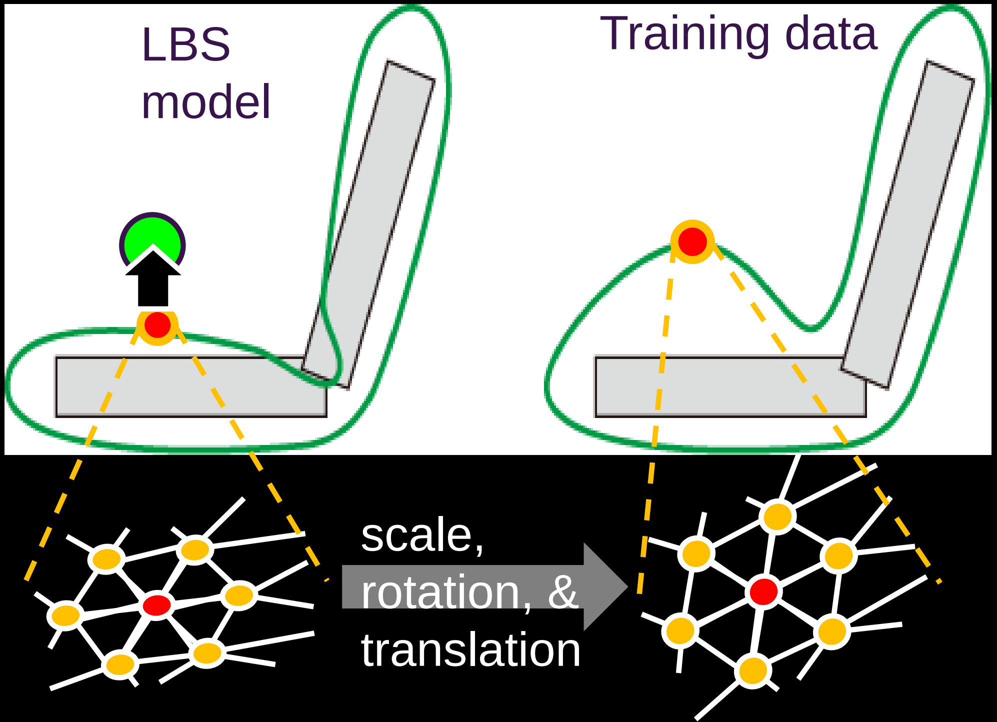
Helper bone rig

Optimization Procedure



Incremental Helper Bone Insertion

1. Find a vertex showing the largest error and its 1-ring neighbors
2. Estimate similarity transformation
3. Inserting a new helper bone using the similarity transformation



SSDS: Smooth Skinning Decomposition with Similarity transformations

training samples

vertices

training shape

skeleton joints

helper bones

$$\min \sum_{q} \sum_{i} \left\| \tilde{\mathbf{v}}_{q,i} - \sum_{j=1}^{J} w_{i,j} \bar{\mathbf{v}}_i \widetilde{\mathbf{M}}_{q,j} - \sum_{h=1}^{H} w_{j,h} \bar{\mathbf{v}}_j \mathbf{S}_{q,h} \mathbf{R}_{q,h} \mathbf{T}_{q,h} \right\|_2^2$$

Subject to $\mathbf{S}_{q,h}$: Non-negative scale , $\mathbf{R}_{q,h}$: Rotation , $\mathbf{T}_{q,h}$: Translation

$w_{i,j}, w_{i,h}$: Non-negative, Partition of unity, Number of non-zeros

SSDS: Block Coordinate Descent - 1

1. Skinning weight optimization [Le 2012]

$$\min \sum_{q} \sum_{i} \left\| \tilde{\mathbf{v}}_{\boldsymbol{q},i} - \sum_{j=1}^{J} \boxed{w_{i,j}} \bar{\mathbf{v}}_i \widetilde{\mathbf{M}}_{\boldsymbol{q},j} - \sum_{h=1}^{H} \boxed{w_{j,h}} \bar{\mathbf{v}}_j \mathbf{S}_{q,h} \mathbf{R}_{q,h} \mathbf{T}_{q,h} \right\|_2^2$$

Subject to $\mathbf{S}_{q,h}$: Non-negative scale , $\mathbf{R}_{q,h}$: Rotation , $\mathbf{T}_{q,h}$: Translation

$w_{i,j}, w_{i,h}$: Non-negative, Partition of unity, Number of non-zeros

SSDS: Block Coordinate Descent - 2

2. Transformation optimization of helper bones

$$\min \sum_{q} \sum_{i} \left\| \tilde{\mathbf{v}}_{\boldsymbol{q},i} - \sum_{j=1}^{J} w_{i,j} \bar{\mathbf{v}}_i \widetilde{\mathbf{M}}_{\boldsymbol{q},j} - \sum_{h=1}^{H} w_{j,h} \bar{\mathbf{v}}_j \boxed{\mathbf{S}_{q,h} \mathbf{R}_{q,h} \mathbf{T}_{q,h}} \right\|_2^2$$

Subject to $\boldsymbol{S}_{q,h}$: Non-negative scale , $\mathbf{R}_{q,h}$: Rotation , $\mathbf{T}_{q,h}$: Translation

$w_{i,j}, w_{i,h}$: Non-negative, Partition of unity, Number of non-zeros

SSDS: Block Coordinate Descent - 2

2.1 Non-uniform scale estimation

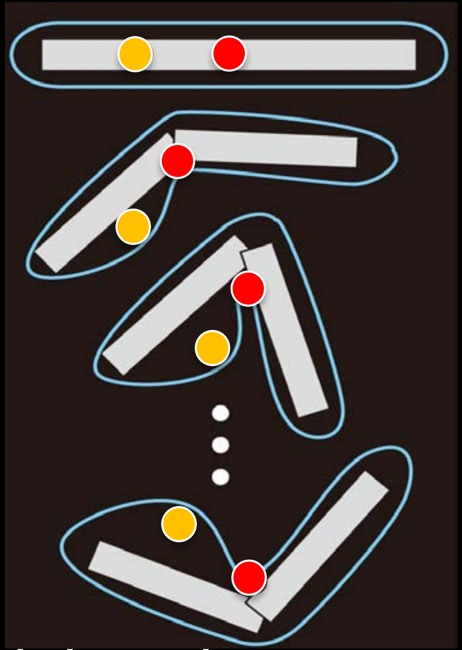
2.2 Rigid transformation estimation

$$\min \sum_{q} \sum_{i} \left\| \tilde{\mathbf{v}}_{\boldsymbol{q},i} - \sum_{j=1}^{J} w_{i,j} \bar{\mathbf{v}}_i \widetilde{\mathbf{M}}_{\boldsymbol{q},j} - \sum_{h=1}^{H} w_{j,h} \bar{\mathbf{v}}_j \underbrace{\left(\boldsymbol{S}_{q,h}\right)}_{\text{NNLS}} \overbrace{\left(\mathbf{R}_{q,h} \mathbf{T}_{q,h}\right)}^{\text{[Horn 1978]}} \right\|_2^2$$

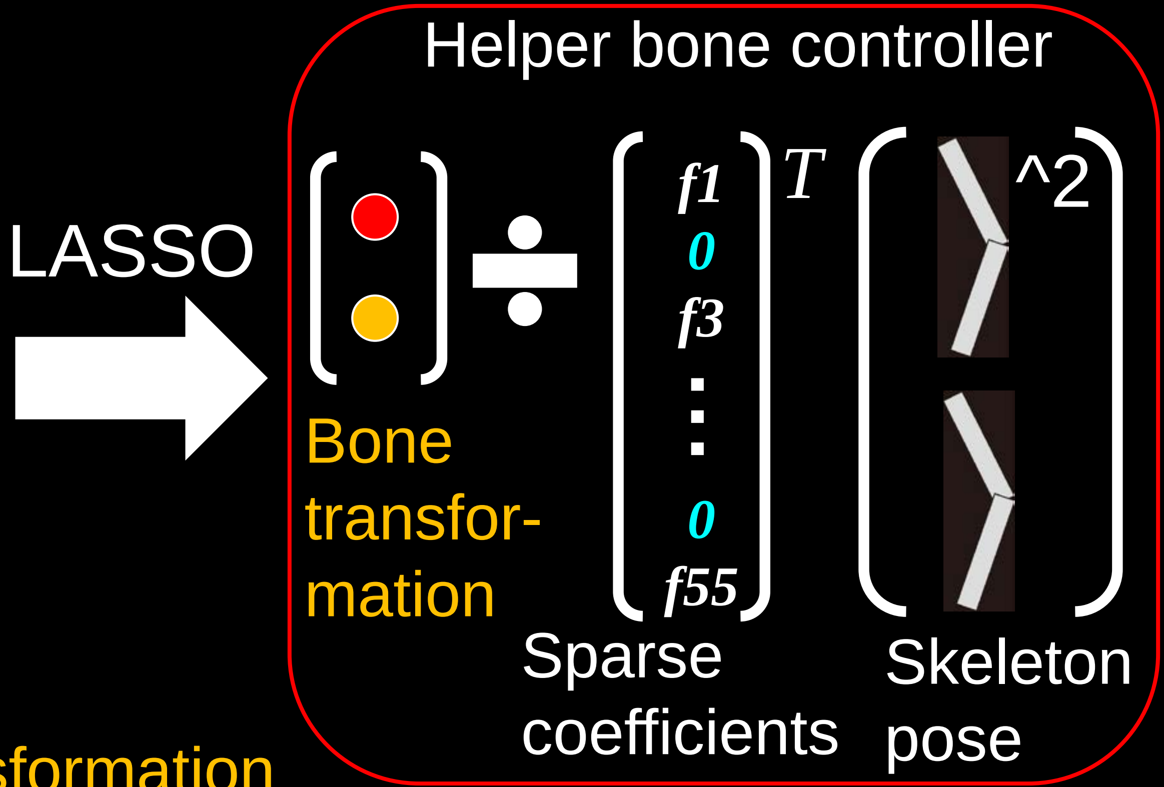
Subject to $\boldsymbol{S}_{q,h}$: Non-negative scale , $\mathbf{R}_{q,h}$: Rotation , $\mathbf{T}_{q,h}$: Translation

$w_{i,j}, w_{i,h}$: Non-negative, Partition of unity, Number of non-zeros

Sparse Regression of Bone Controller



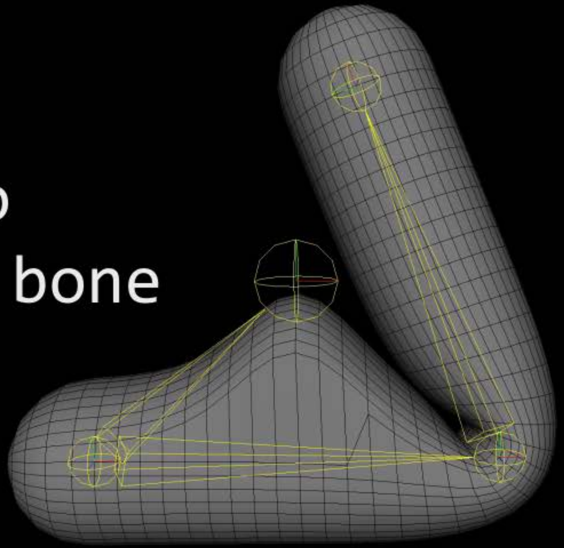
Training shapes
+ helper bone transformation



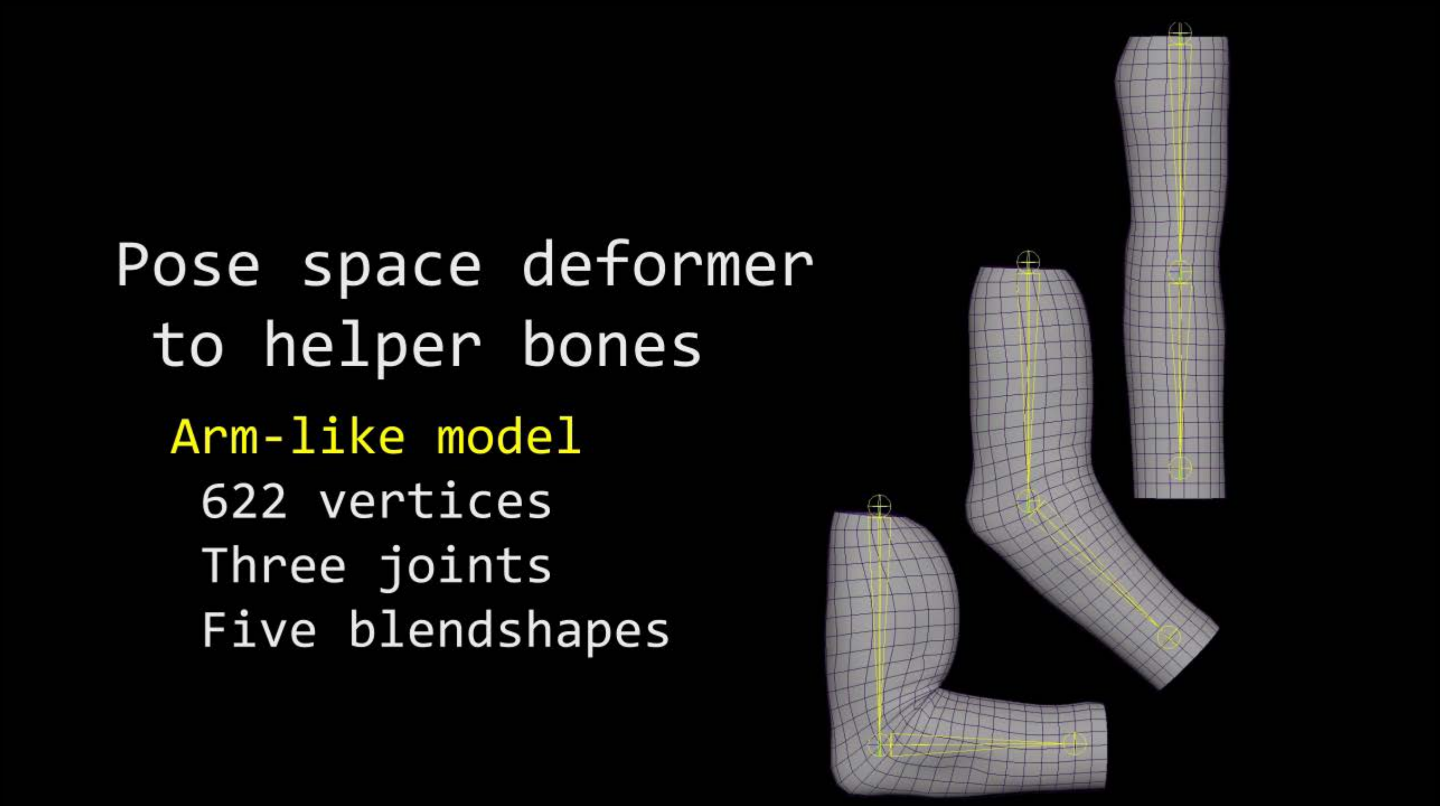
from Rigid Helper Bone

Rigid Helper bone to
Non-rigid helper bone

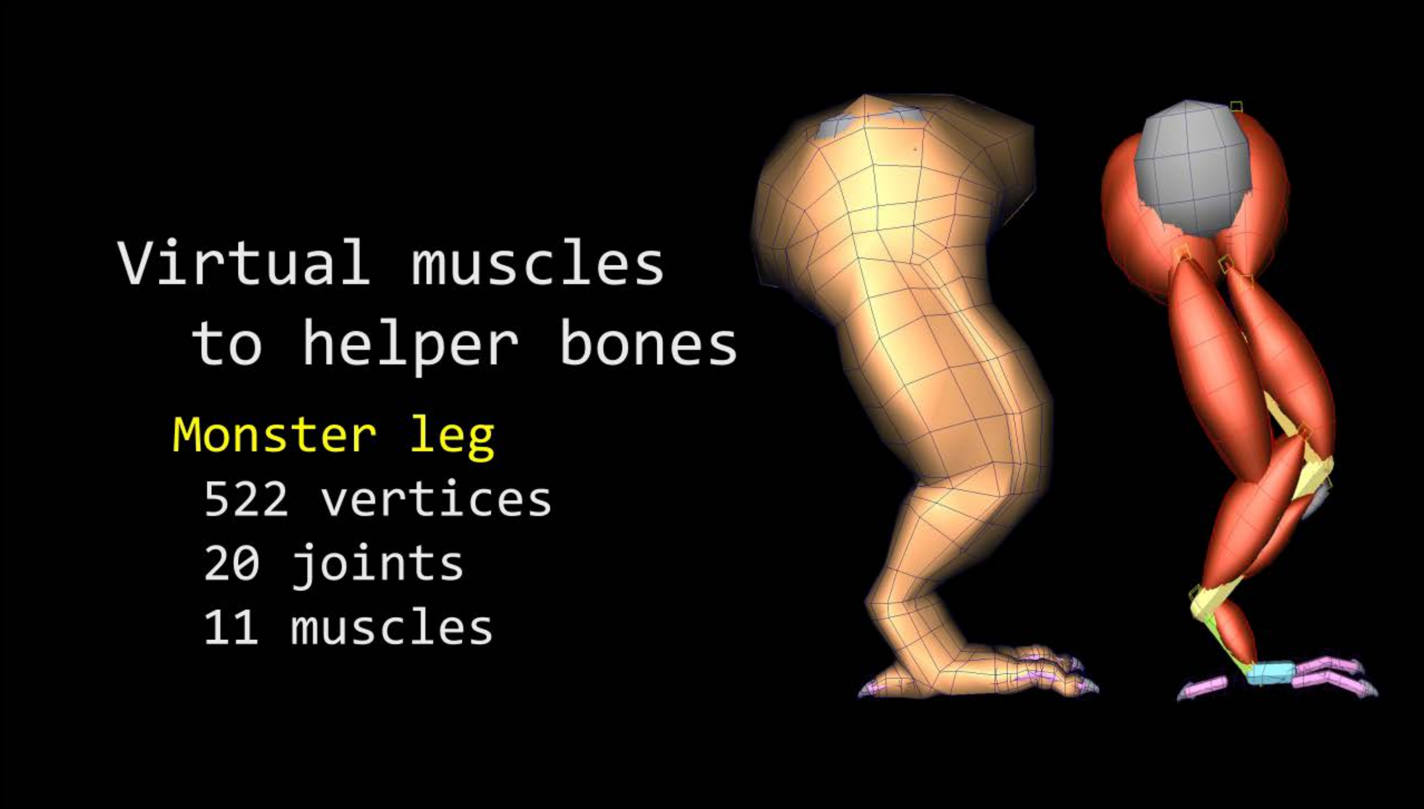
Bulging cylinder
1962 vertices
Three joints
One helper bone



from Pose Space Deformation



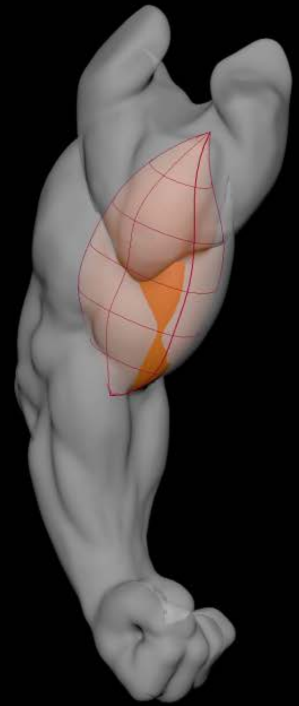
from Virtual Muscles



from Virtual Muscles

Virtual muscles
to helper bones

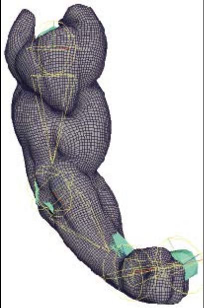
Exaggerated arm
15768 vertices
Four joints
One muscle



Limitations

- Only skeleton-driven deformer
  - not support cage-based deformers or blendshapes
- No theoretical grounding on optimality
- Only vertex position, not vertex normal
- Low editability of helper bone controllers

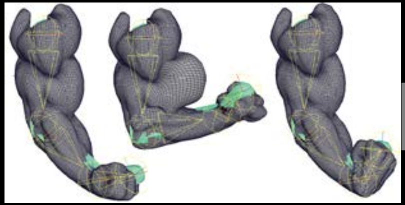
Summary



Source rig
(skeleton-driven
deformer)

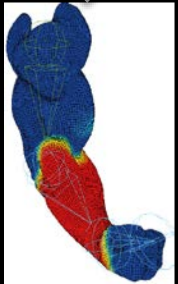
Two-step sampling

Displacement
& dependency
measure



Training samples

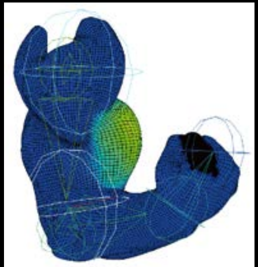
Data-driven skinning



LBS rig with
no helper

Non-rigid helper bone rigging

SSDS algorithm &
Sparse regression



Non-rigid helper bones

Acknowledgement: JSPS KAKENHI 15K16110 & 15H02704, PlatinumGames Inc.