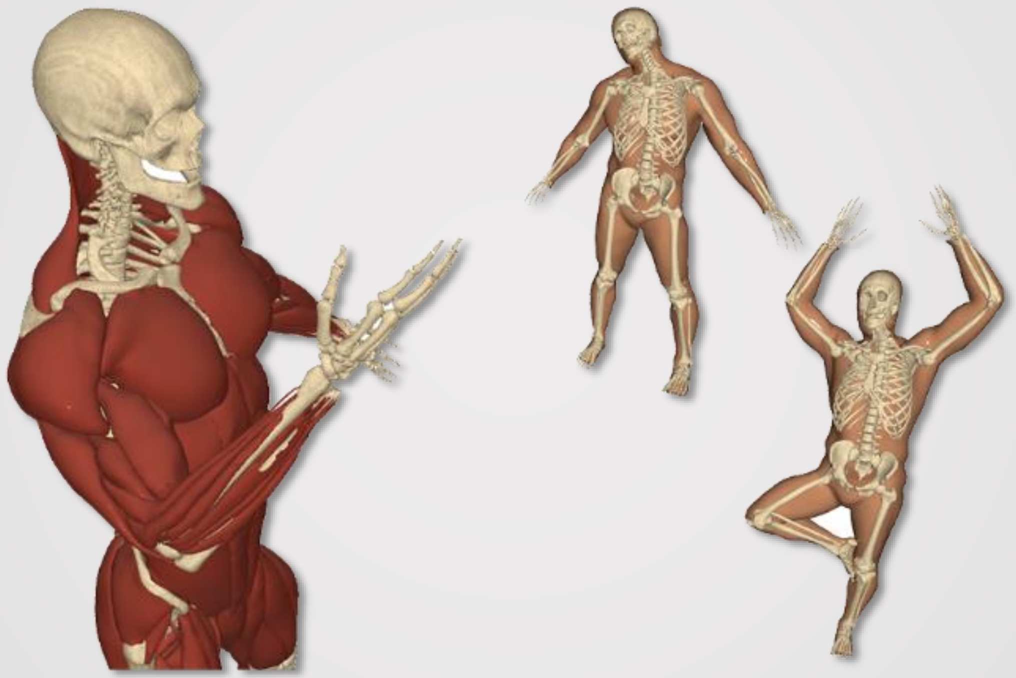
Reconstructing Personalized Anatomical Models for Physics-based Body Animation



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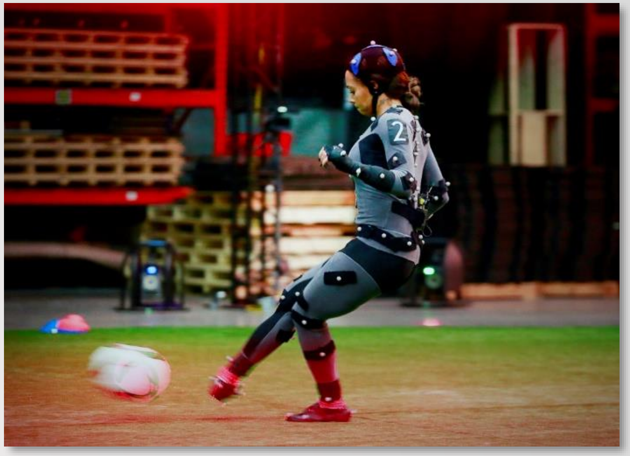
MOTIVATION

1. Build an anatomical rigged volumetric model from 3D scan data.

2. Animate through physics simulation.
   e.g. with MOCAP data.

MOTIVATION

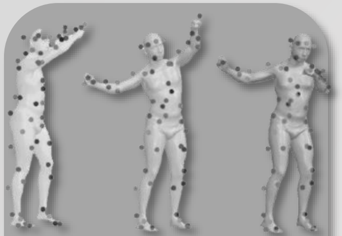


MOTIVATION

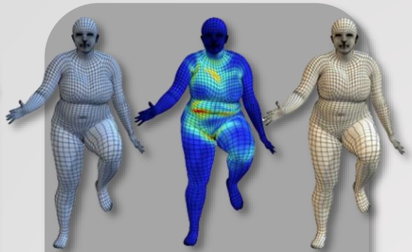
MOTIVATION


render with fur/hair/tail/mane simulation
Image courtesy of Weta Digital

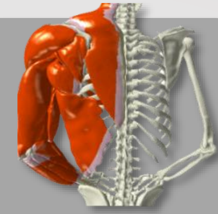
RELATED WORK



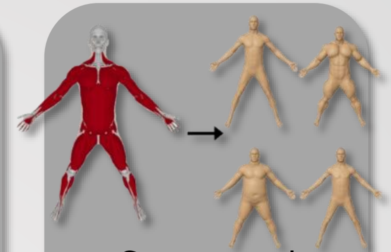
SCAPE,
Anguelov et al., SG'05



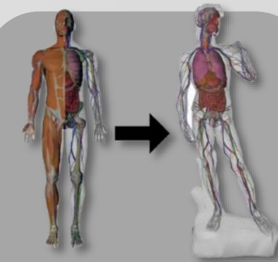
DYNA,
Pons-Moll et al., SG'15



Creating and Simulating Skeletal Muscle from the Visible Human Data Set,
Teran et al., VCG'05



Computational Bodybuilding,
Saito et al., SG'15

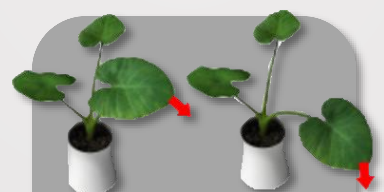


Anatomy Transfer,
Dicko et al., SG'13

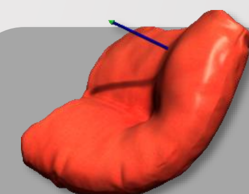
Data-driven

Forward Simulation Only

An asymptotic numerical method for inverse elastic shape design,
Chen et al., SG'14



Deformation Capture and Modeling of Soft Objects,
Wang et al., SG'15



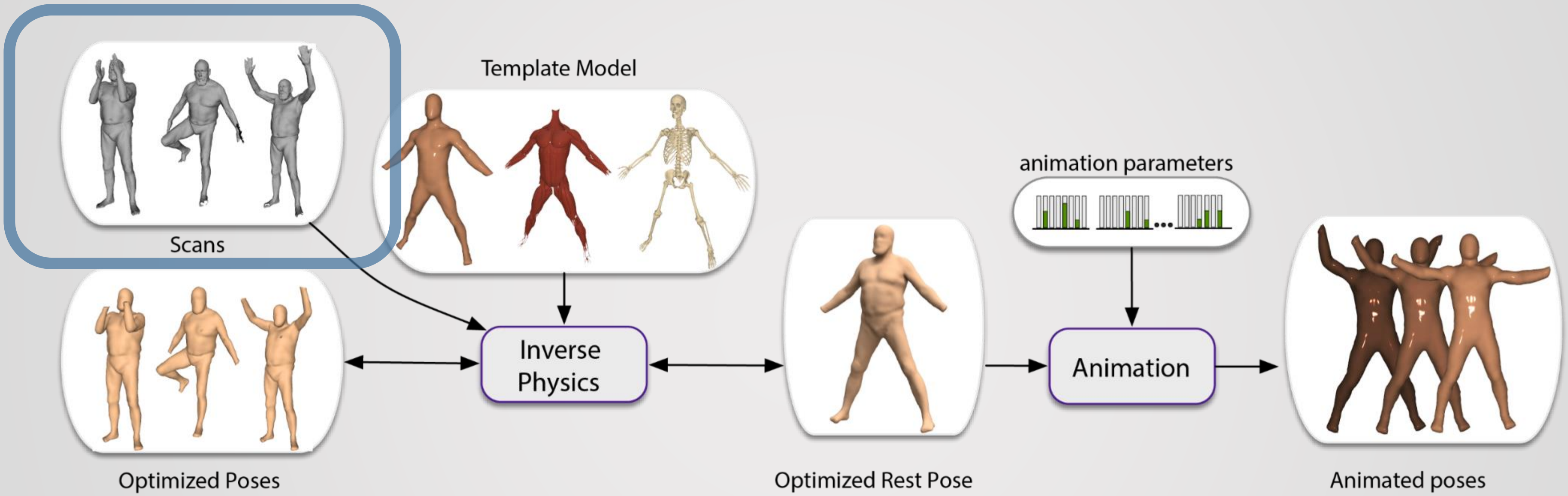
Capture and Modeling of Non-Linear Heterogeneous Soft Tissue,
Bickel et al., SG'09

Inverse Material Modeling

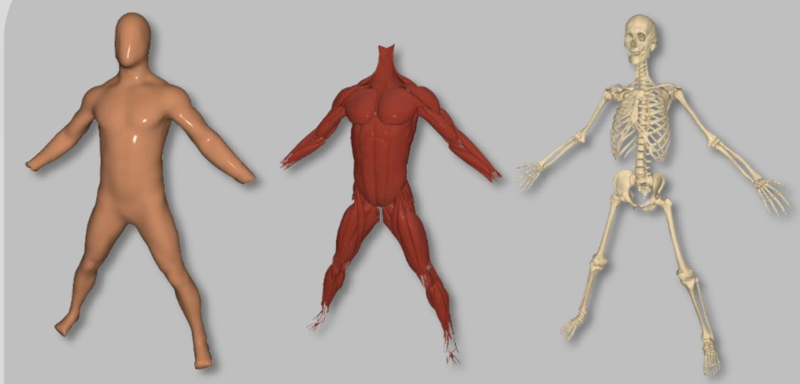
CONTRIBUTIONS

- First method to reconstruct a fully physics-based subject-specific anatomical model
- New elastic potential more suitable for solving the inverse reconstruction problem
- Use different material types and growth models
- Collisions at reconstruction time

PIPELINE

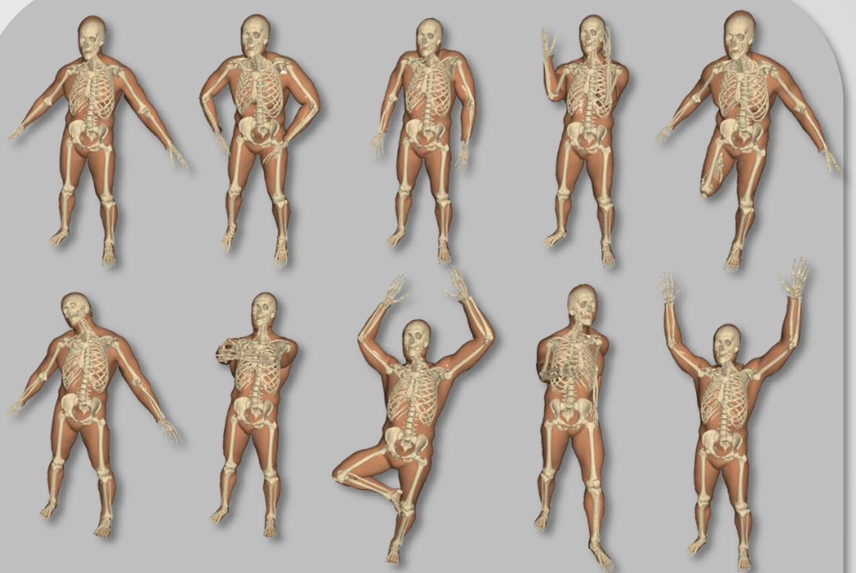

Template Model
animation parameters
Scans
Inverse Physics
Animation
Optimized Poses
Optimized Rest Pose
Animated poses

TEMPLATE MODEL



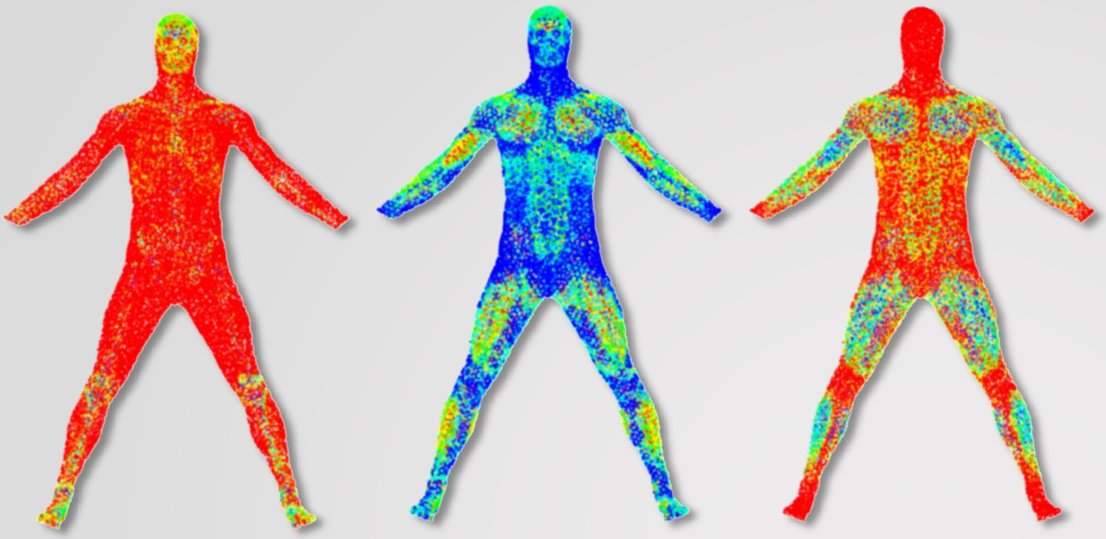
Tetrahedral mesh
Rigged with a skeleton.

The bones and tetmesh talk
through sampled bone vertices.



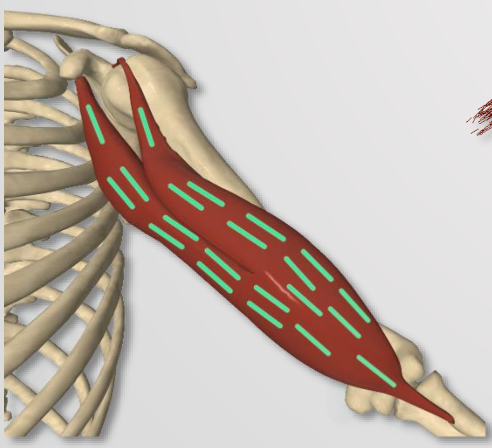
The skeleton offers both pose and
character-specific parametrization.

TEMPLATE MODEL



Types of materials
(non-conformally embedded):

- Bone
- Muscles and tendons
- Generic Soft Tissue / Fat

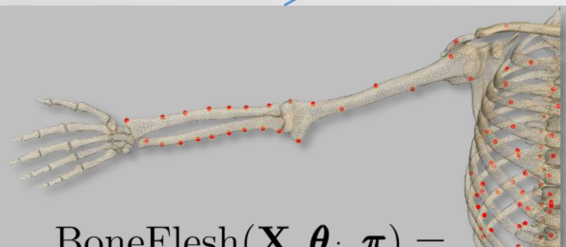


Muscle fiber directions.

PHYSICS-BASED SKINNING

Solve the optimization problem: $\mathrm{Skin}(\mathbf{X}^{\mathrm{src}}, \boldsymbol{\theta}_i, \boldsymbol{\pi}) = \underset{\mathbf{X}}{\operatorname{argmin}}\, E_{\mathrm{skin}}(\mathbf{X}^{\mathrm{src}}, \mathbf{X}, \boldsymbol{\theta}_i, \boldsymbol{\pi})$

$$E_{\mathrm{skin}}(\mathbf{X}^{\mathrm{src}}, \mathbf{X}, \boldsymbol{\theta}_i, \boldsymbol{\pi}) = \mathrm{BoneFlesh}(\mathbf{X}, \boldsymbol{\theta}_i, \boldsymbol{\pi}) + E_{\mathrm{def}}(\mathbf{X}^{\mathrm{src}}, \mathbf{X}) + E_{\mathrm{grav}}(\mathbf{X}) + E_{\mathrm{col}}(\mathbf{X})$$

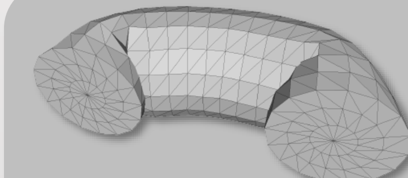


$$\mathrm{BoneFlesh}(\mathbf{X}, \boldsymbol{\theta}_i, \boldsymbol{\pi}) = w_{\mathrm{bone}} \left\| \mathbf{S}^{\mathrm{bone}} \mathbf{X} - \mathrm{Rig}(\boldsymbol{\theta}_i, \boldsymbol{\pi}) \right\|^2$$

Skeletal Motion

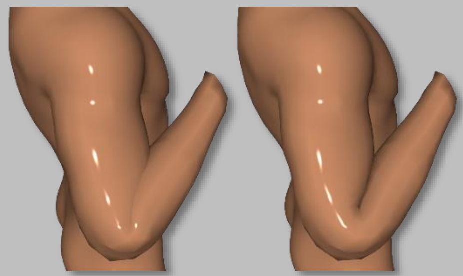
Pose changes

Bone lengths



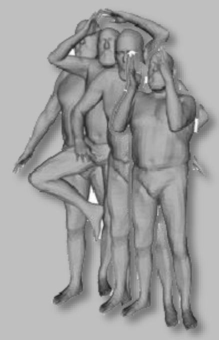
Deformation Energy

Gravity



Collisions

INVERSE PHYSICS REGISTRATION



Scan Targeting

$$\min_{\mathbf{X}^{\text{pers}},\mathbf{X}_k^{\text{arti}},\boldsymbol{\pi},\boldsymbol{\theta}_k} E_{\text{targ}}(\mathbf{X}_k^{\text{arti}}) + E_{\text{reg}}(\mathbf{X}^{\text{pers}},\boldsymbol{\pi})$$

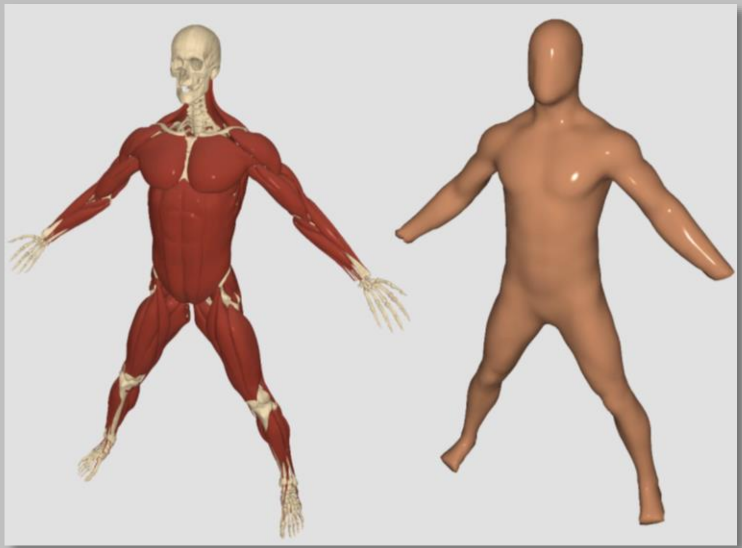
$$\text{subject to } \nabla_{\mathbf{X}_k^{\text{arti}}} E_{\text{skin}}(\mathbf{X}^{\text{pers}},\mathbf{X}_k^{\text{arti}},\boldsymbol{\theta}_k,\boldsymbol{\pi}) = 0$$

Skinning Energy (at steady state)

Muscle growth orthogonal to fibers

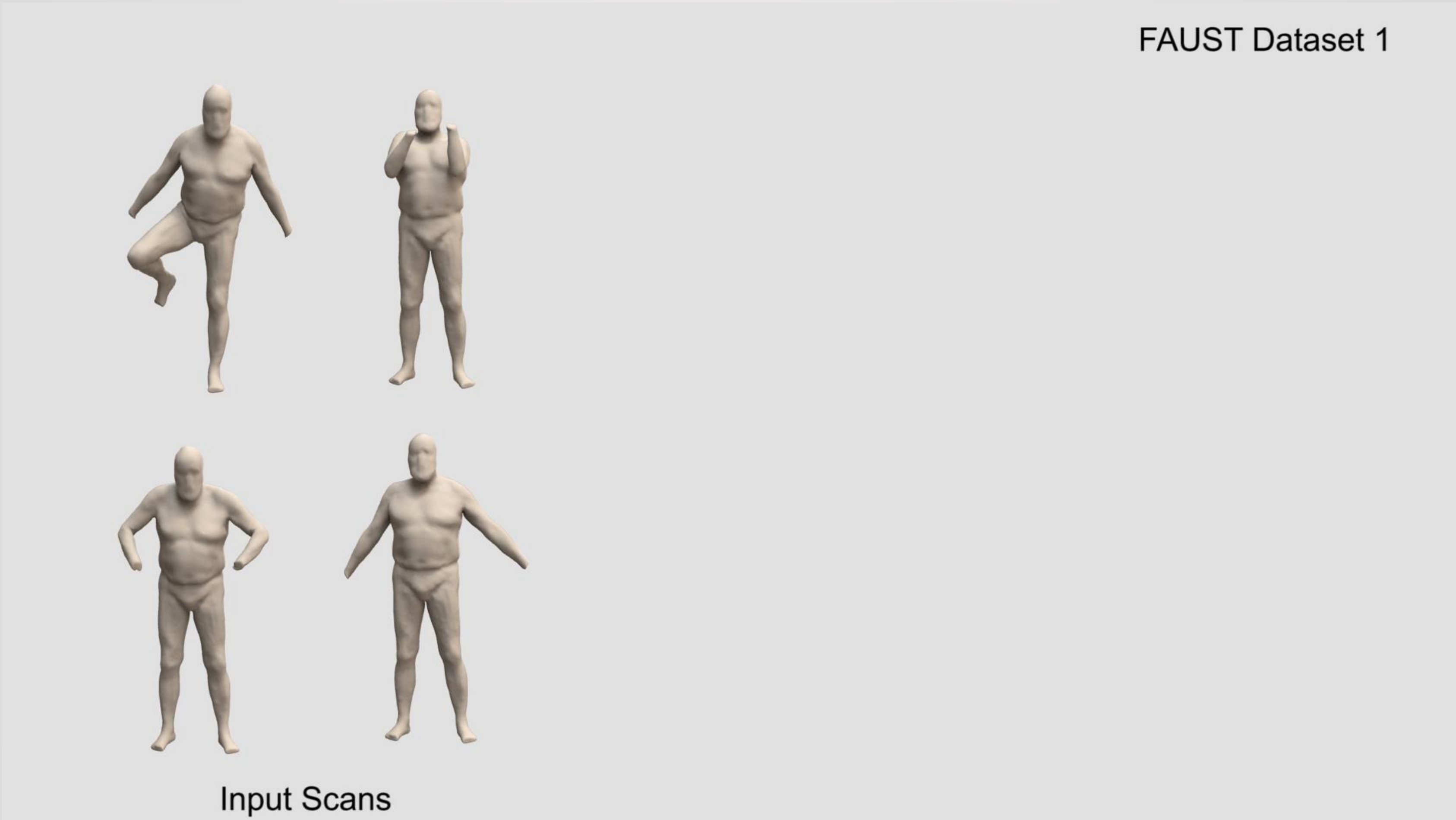
$$\mathbf{S}(\alpha_i) = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \alpha_i & 0 \\ 0 & 0 & \alpha_i \end{pmatrix}$$

Fat grows freely in the remaining space

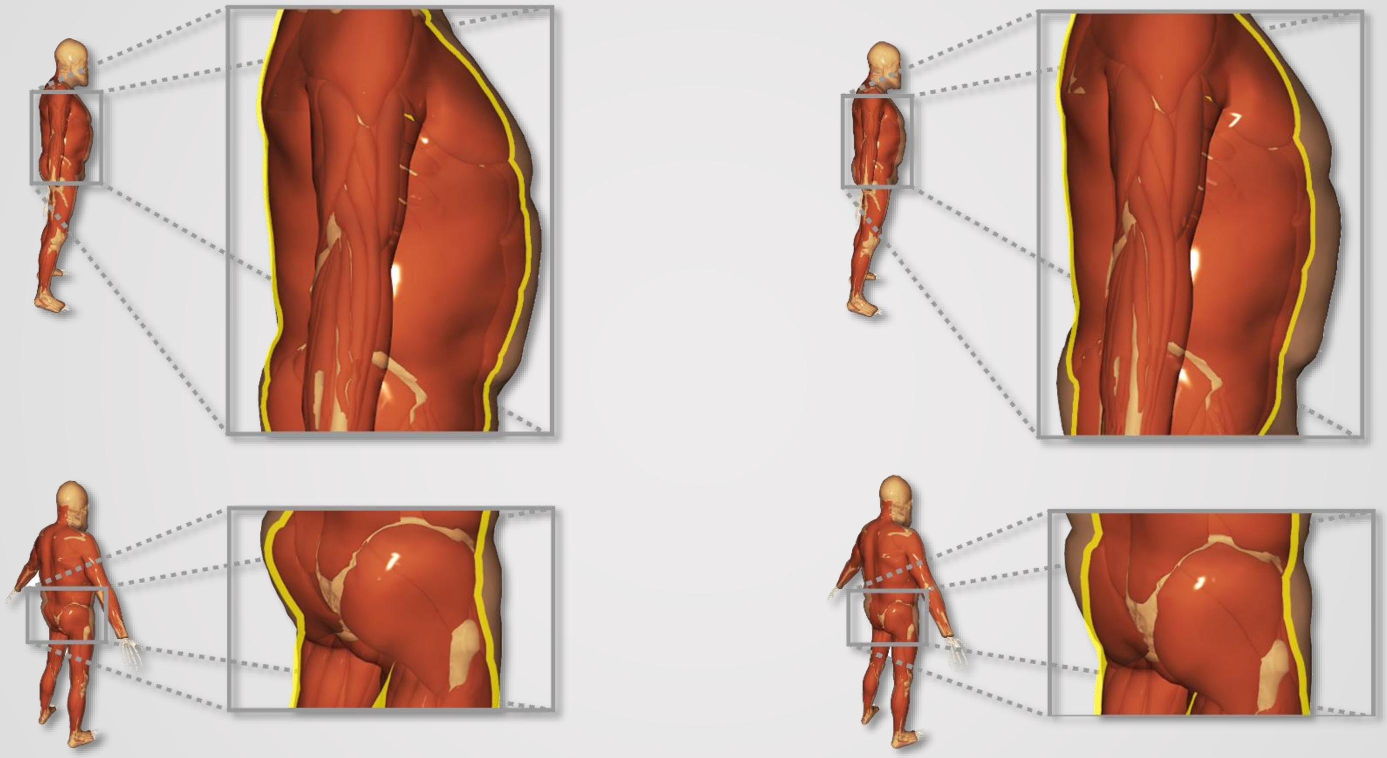


Growth Priors

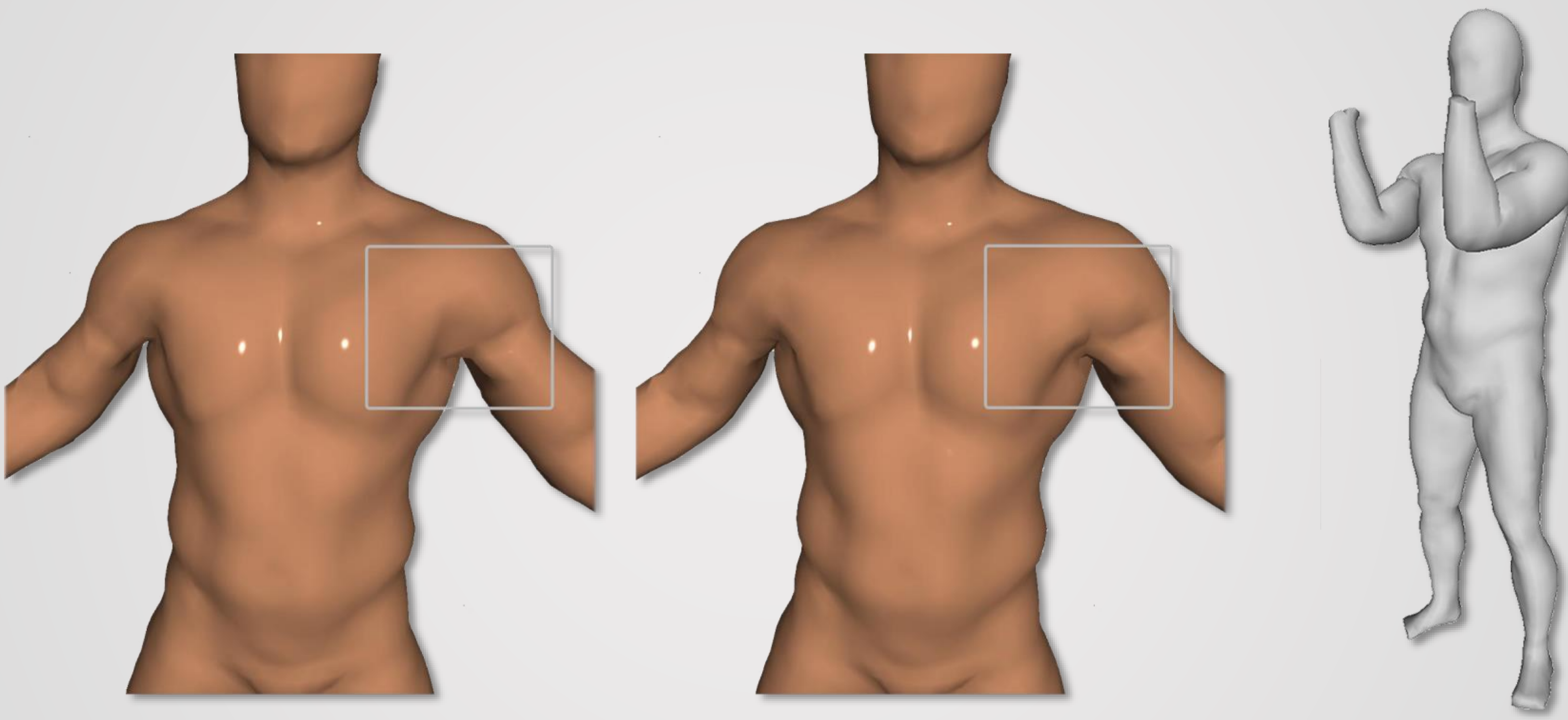
INVERSE PHYSICS REGISTRATION



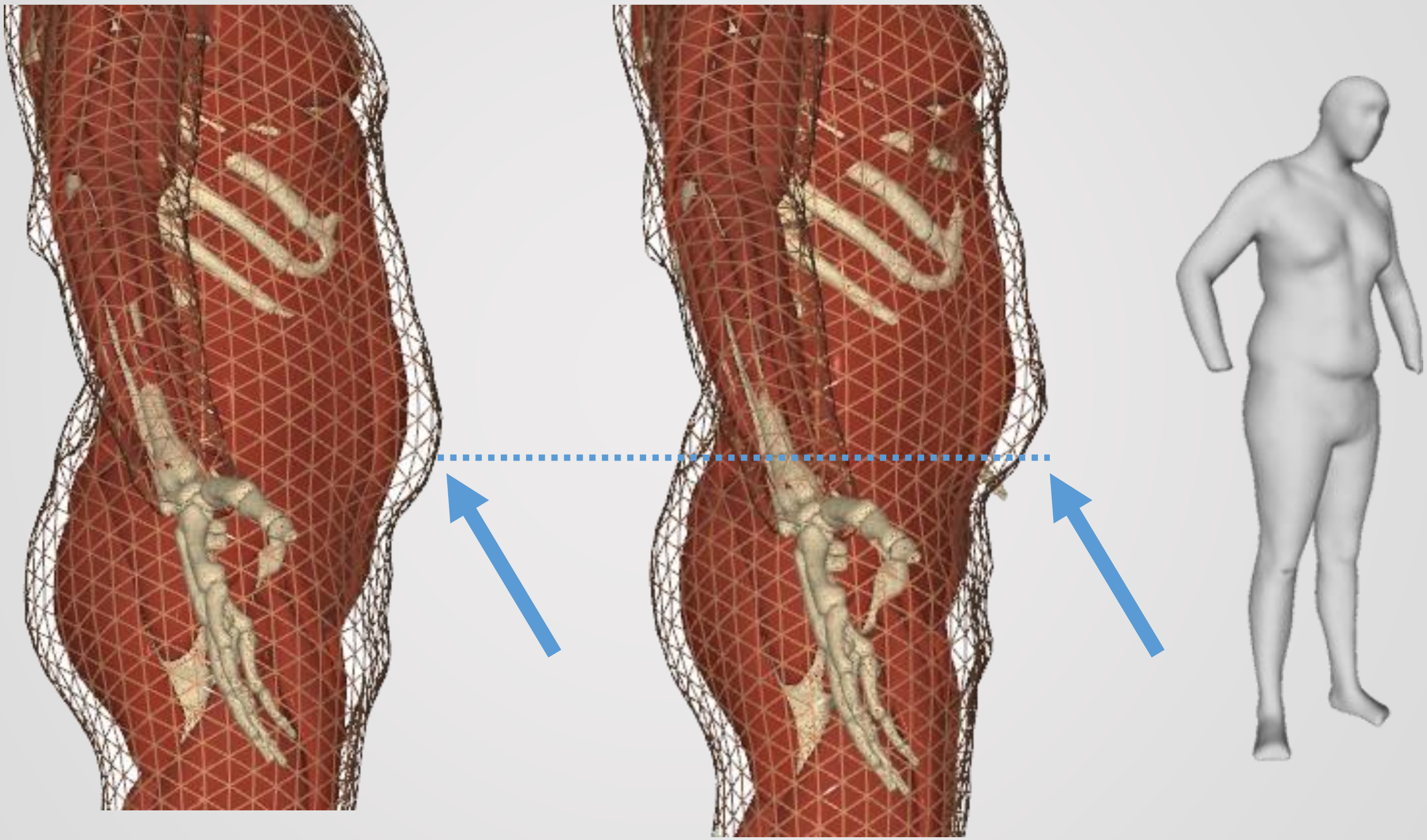
RESULTS – GROWTH MODEL



RESULTS – INVERSE COLLISIONS



RESULTS – INVERSE GRAVITY



ANIMATION

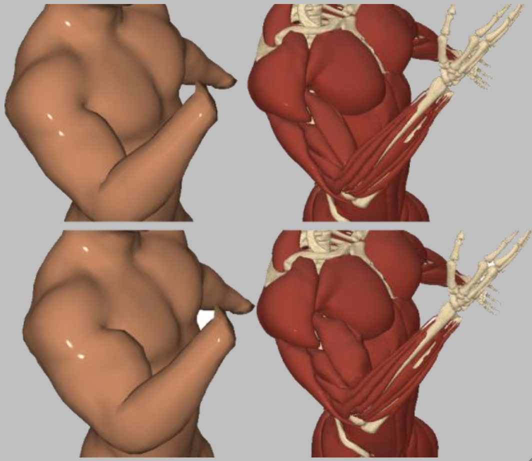
$$\text{Skin}(\mathbf{X}^{\text{src}}, \boldsymbol{\theta}_i, \boldsymbol{\pi}) = \underset{\mathbf{X}}{\text{argmin}}\, E_{\text{skin}}(\mathbf{X}^{\text{src}}, \mathbf{X}, \boldsymbol{\theta}_i, \boldsymbol{\pi}) + E_{inertia}(\mathbf{X}^{\text{src}}) + E_{contraction}(\mathbf{X}^{\text{src}}, \boldsymbol{\beta})$$

Inertia Term

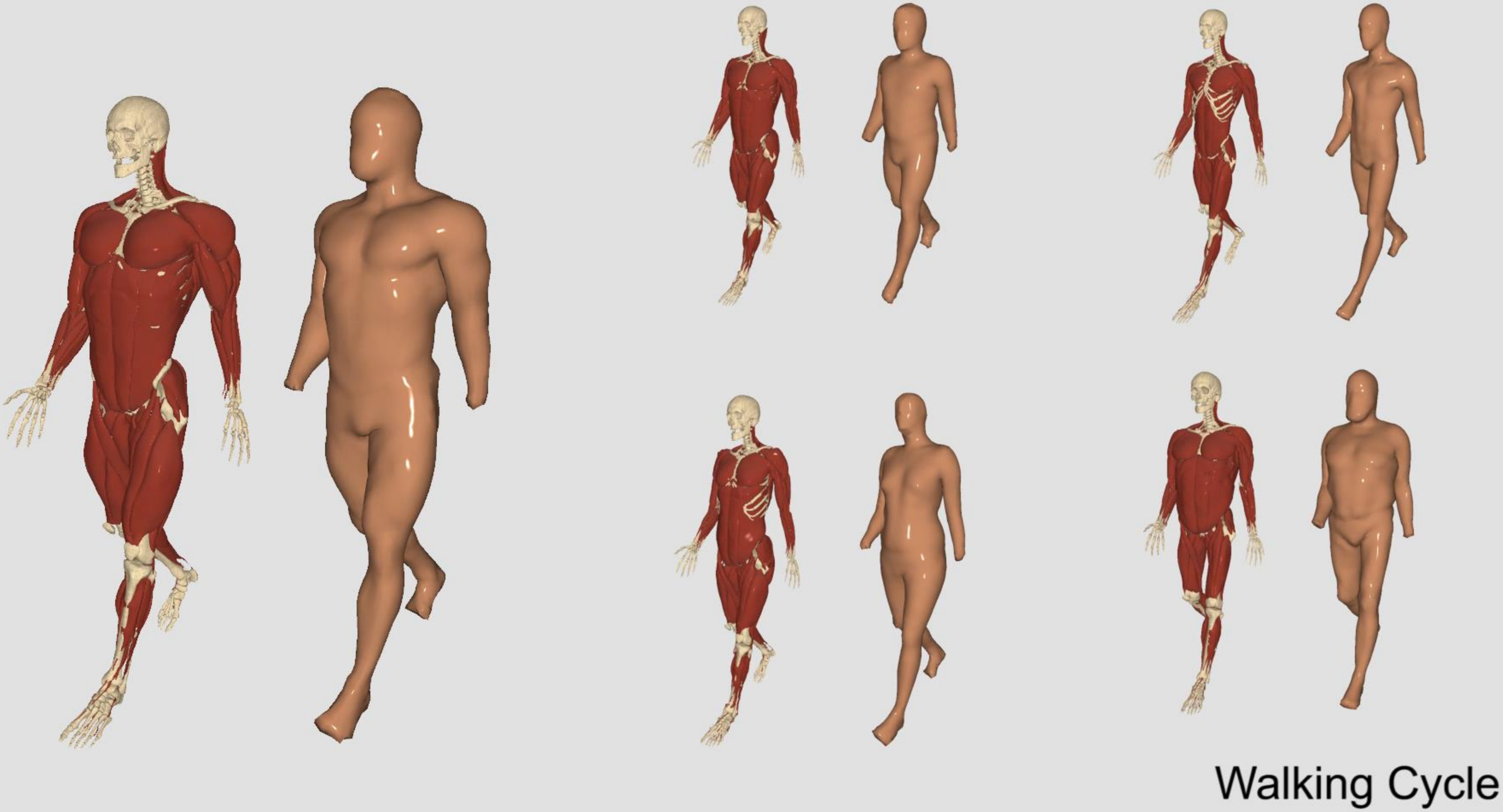
$$E_{inertia}(\mathbf{X}) = \frac{1}{2h^2}\|\mathbf{M}^{1/2}(\mathbf{X} - 2\mathbf{X}_j^{\text{anim}} + \mathbf{X}_{j-1}^{\text{anim}})\|^2$$

Volume-preserving muscle contraction along fibers

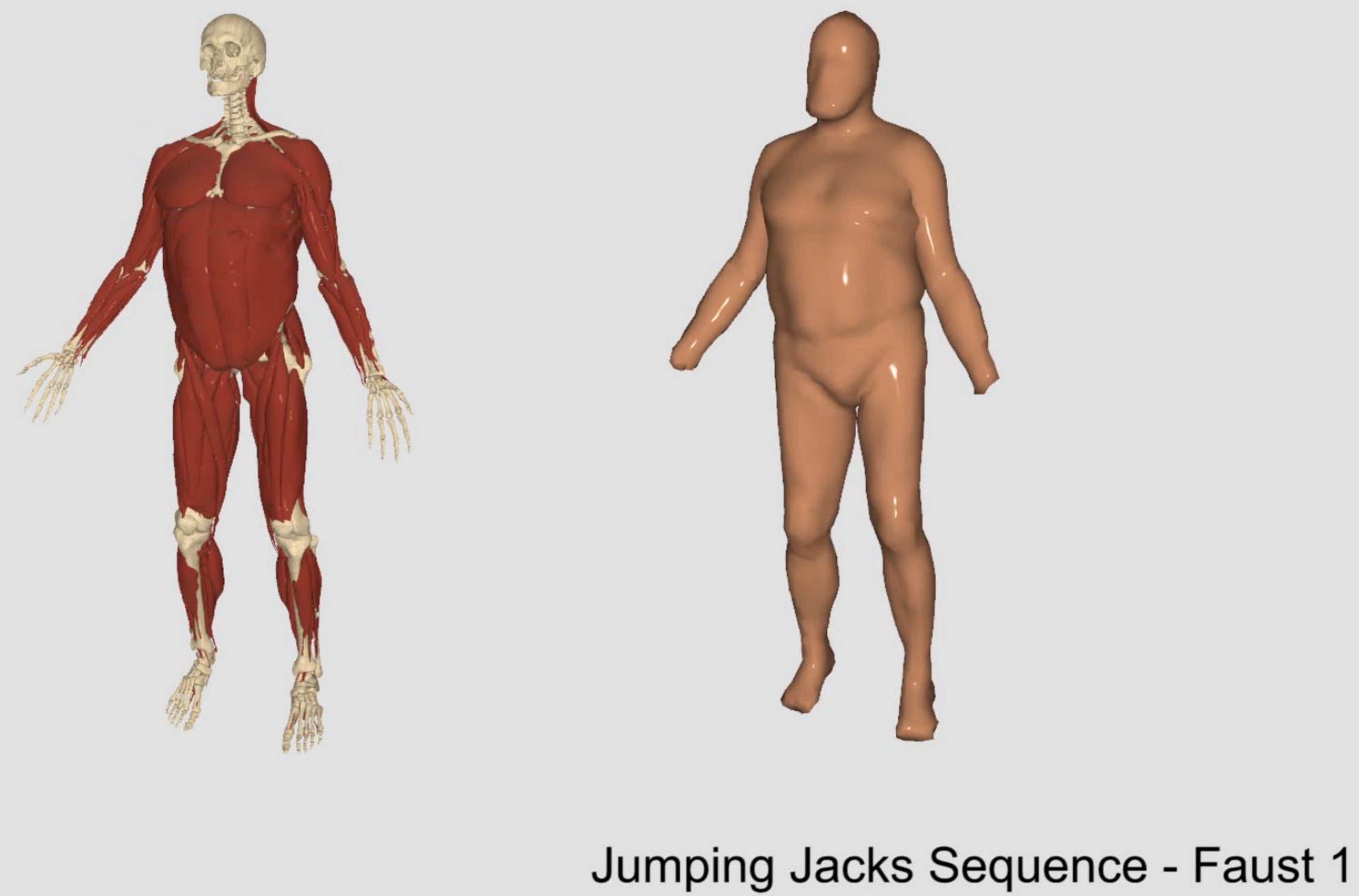
$$\mathbf{S}(\beta_i) = \begin{pmatrix} \beta_i^{-1} & 0 & 0 \\ 0 & \sqrt{\beta_i} & 0 \\ 0 & 0 & \sqrt{\beta_i} \end{pmatrix}$$



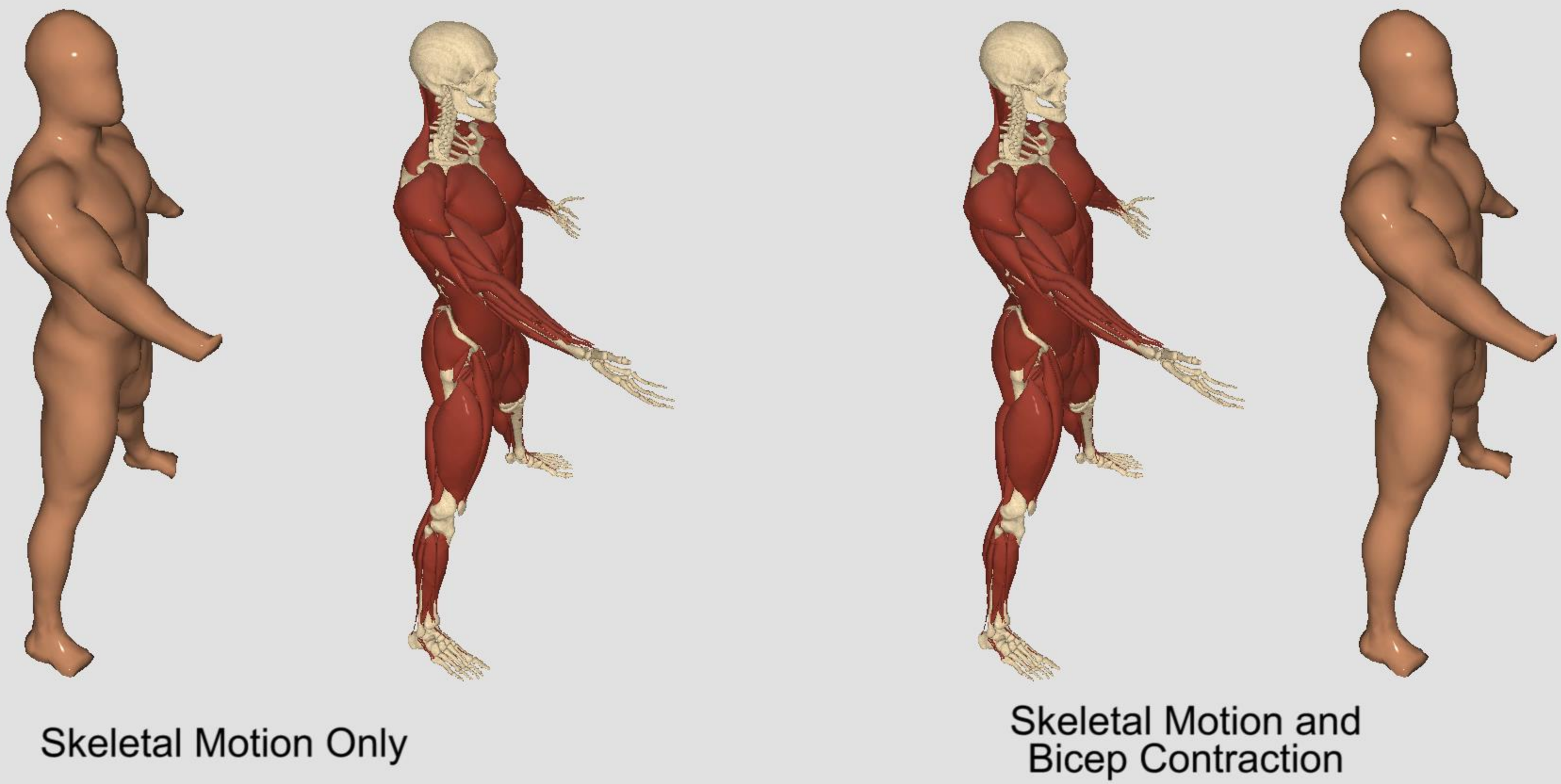
RESULTS – MOCAP ANIMATION



RESULTS – INERTIAL EFFECTS



RESULTS – MUSCLE CONTRACTION



LIMITATIONS AND FUTURE WORK

- Only capture large- and medium-scale details. The quality of the results depends on the template model.
- Muscle-bone interactions, e.g., collisions, sliding
- Due to the complexity of the optimization problem, we cannot scale to fitting more than 10 scans at the same time.
- Can only handle real scans. Fantastical creatures might need a different template model.

- Estimate the muscle contractions/forces from the scans.
- Perform reconstructions from sequences of scans, where the body is not in a steady-state.

- Biomechanics and computer graphics

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Thank you for your attention.

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* joint first authors