DRAPE : DRessing Any PErson

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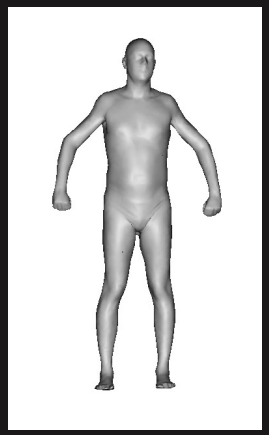
BROWN

Conflict of Interest Disclosure: Black is a founder and shareholder of *Any Body Inc.*, which has plans to commercialize 3D body shape technology.

MAX-PLANCK-GESELLSCHAFT

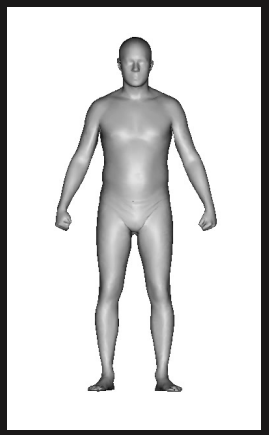
Contribution: Dress any person automatically (any shape, any pose)

shape



+

pose



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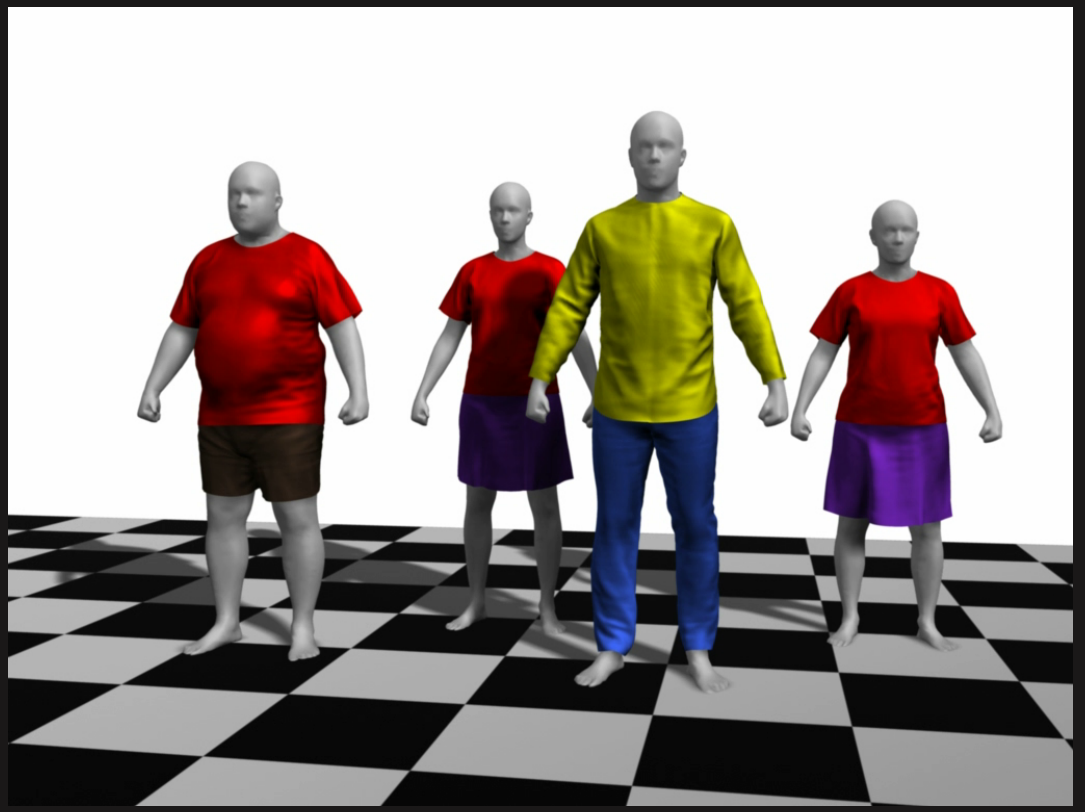
DRAPE



Realism
Speed
Automation

Clothing simulation (quality)

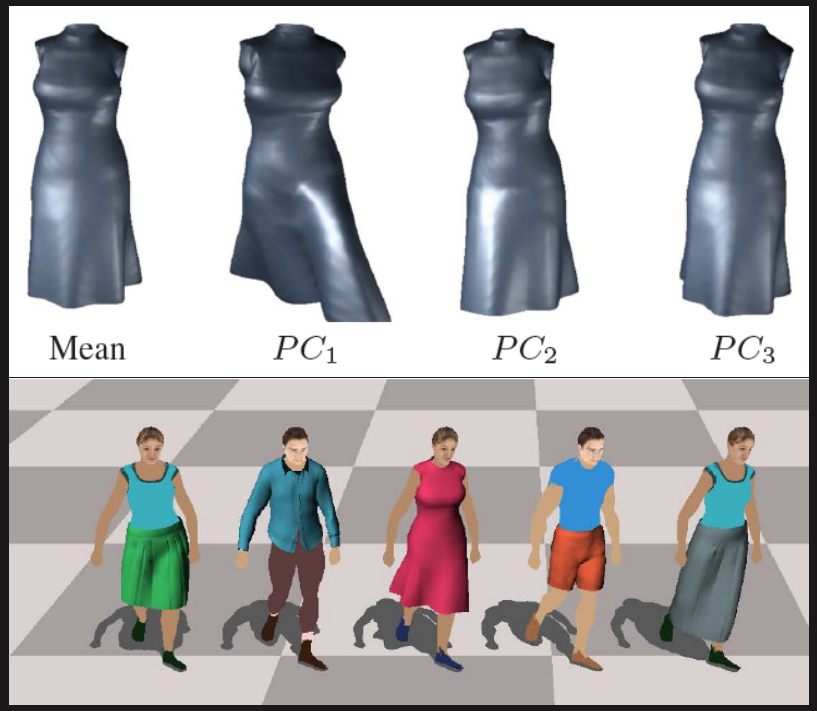
R. Goldenthal et al. SIGGRAPH 2007

D. Baraff et al. SIGGRAPH 2003
K.J. Choi and H.S. Ko SIGGRAPH 2002
R. Bridson et al. SCA 2003
and many more

Realism:

- High quality cloth model
- High-res physical-simulation

Clothing simulation (speed, data-driven)

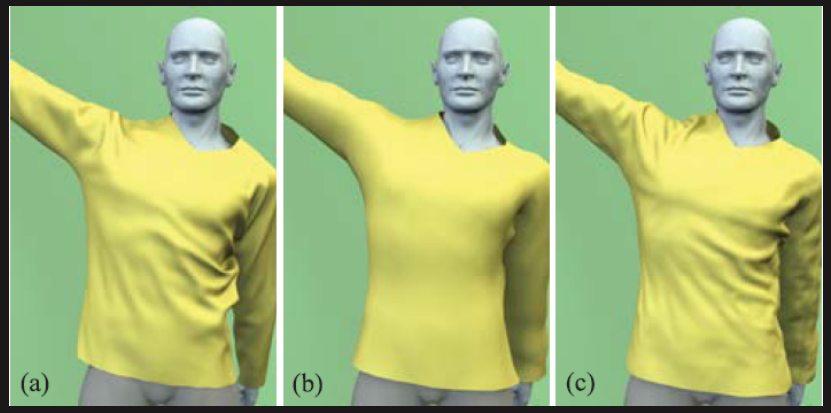


E.D. Aguiar et al. SIGGRAPH 2010

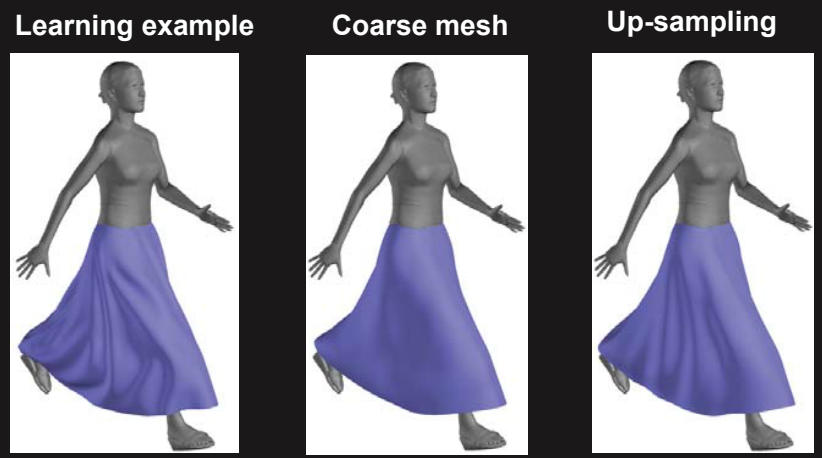
Real-time speed:

- Low dimensional reduced model
- Dynamics in the reduced space

Clothing simulation (speed + quality)



H. Wang et al. SIGGRAPH 2010

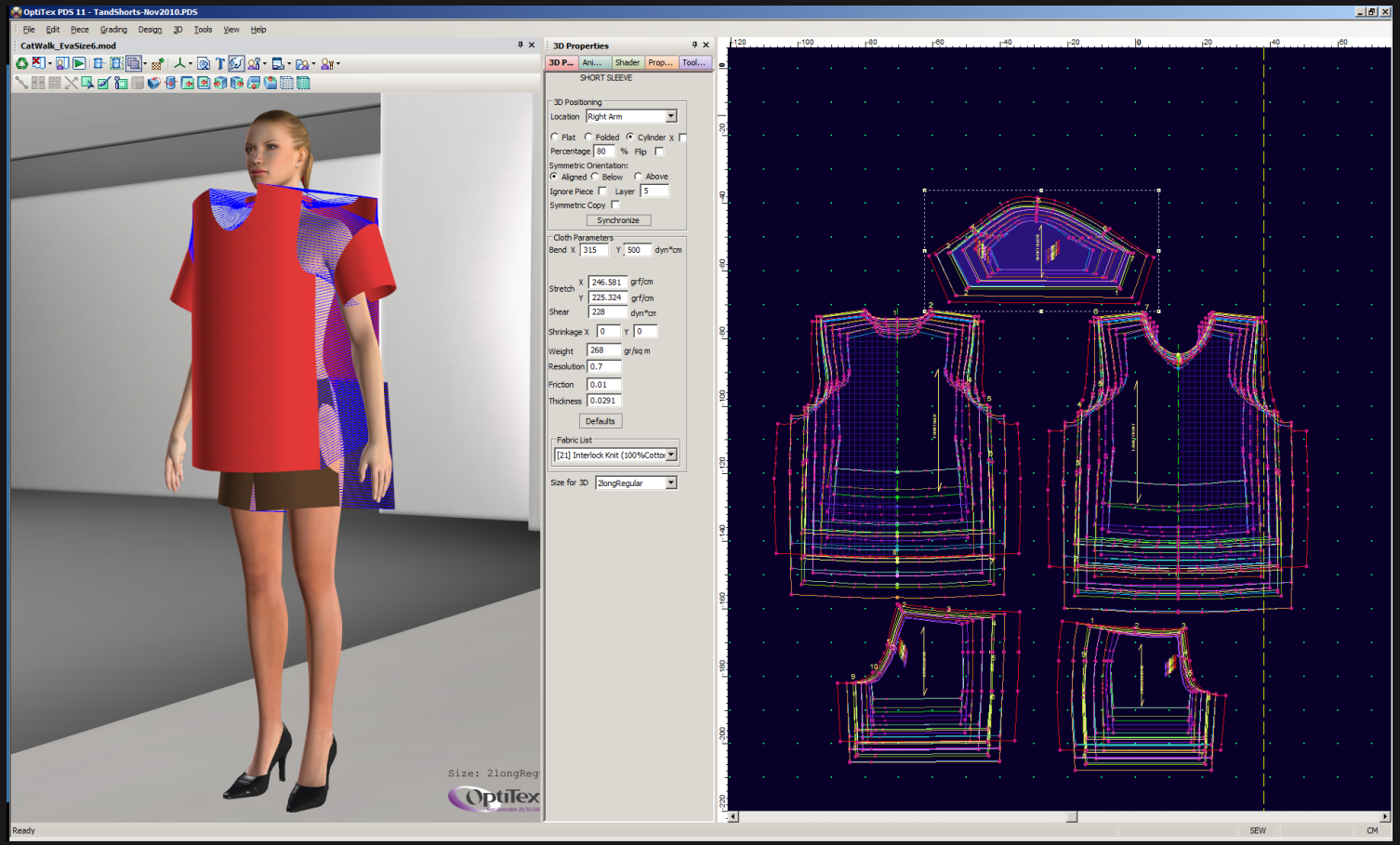


L. Kavan et al. SIGGRAPH 2010

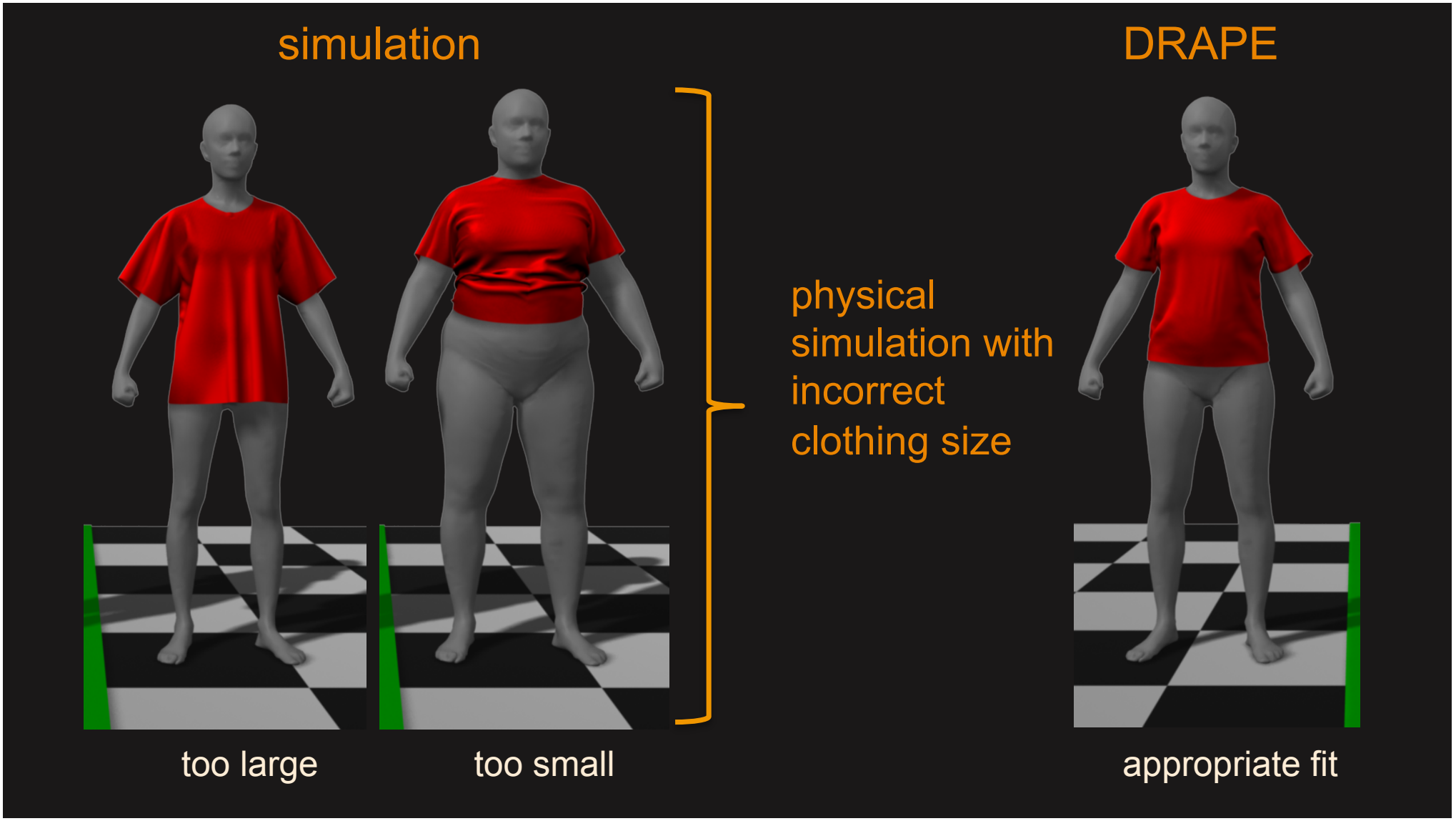
Balance speed and quality:

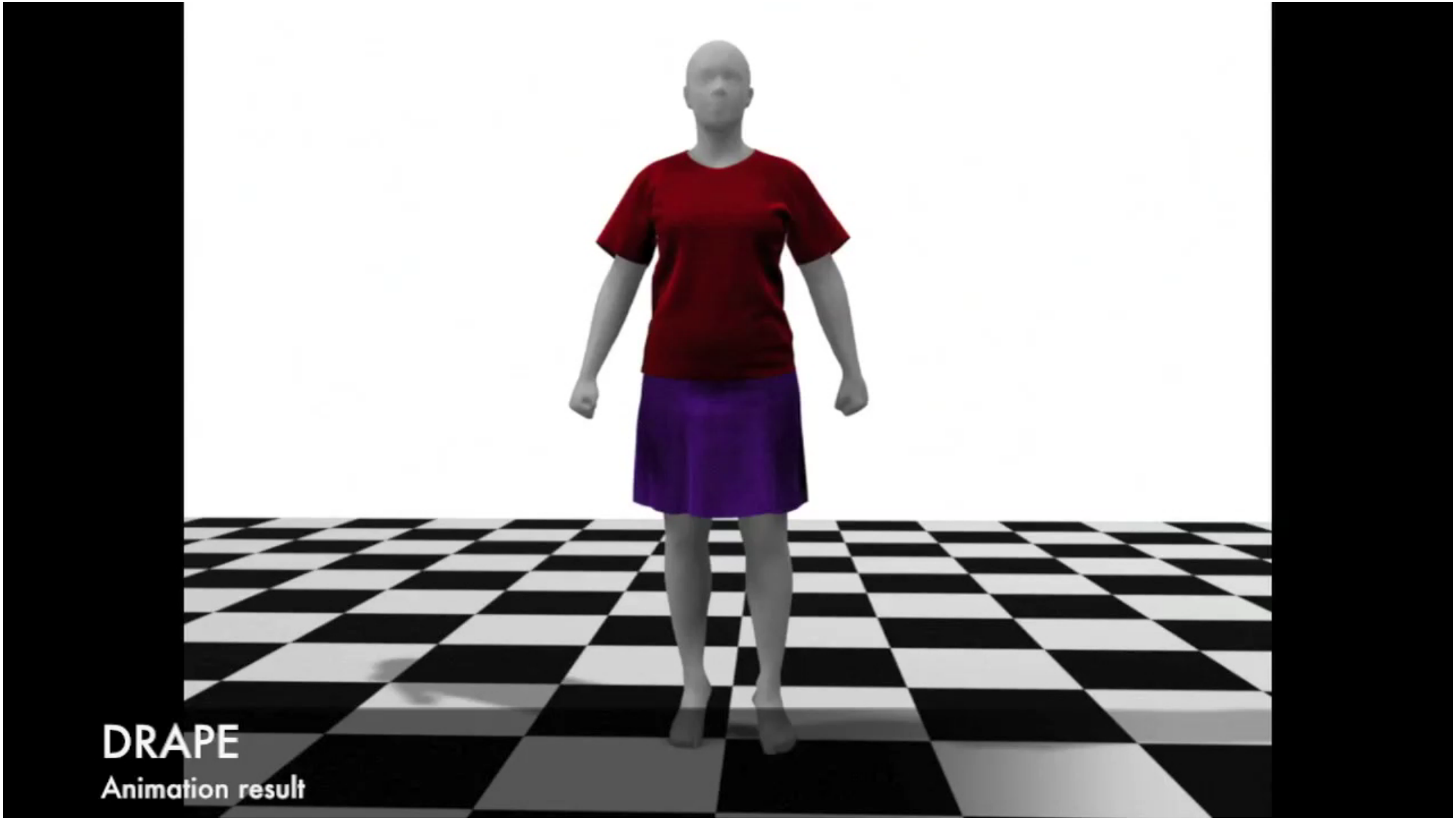
- Low-res physical-simulation
- Mapping to high-res mesh

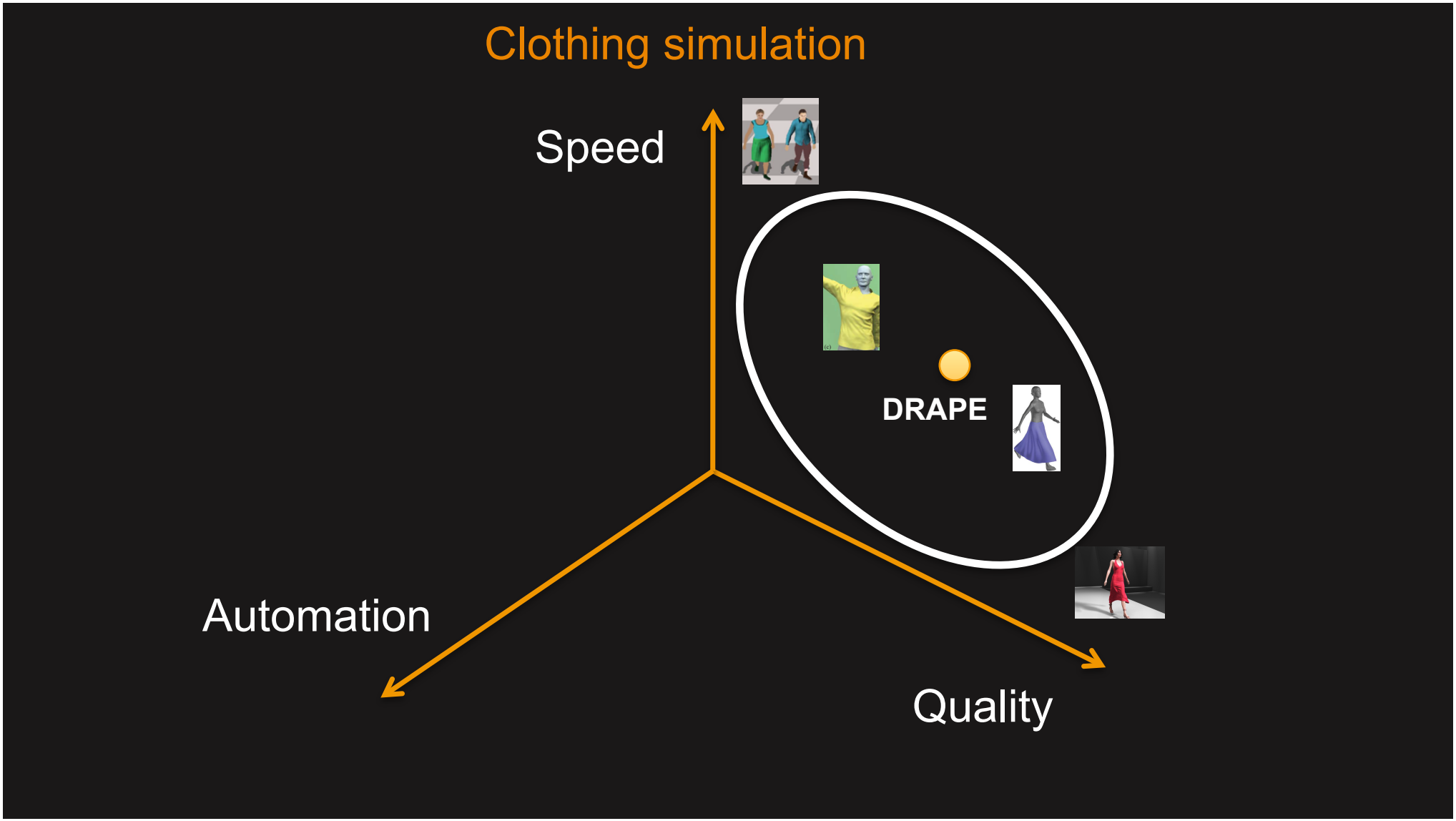
Problem : A lot of manual effort



Screenshot from OptiTex – standard pattern design and simulation software


simulation
DRAPE
physical simulation with incorrect clothing size
too large
too small
appropriate fit


DRAPE
Animation result


Clothing simulation
Speed
DRAPE
Automation
Quality

Applications that require automatic customized fit

OptiTex

Virtual try-on:

- Arbitrary 3D body shape
- Visualize clothing fit

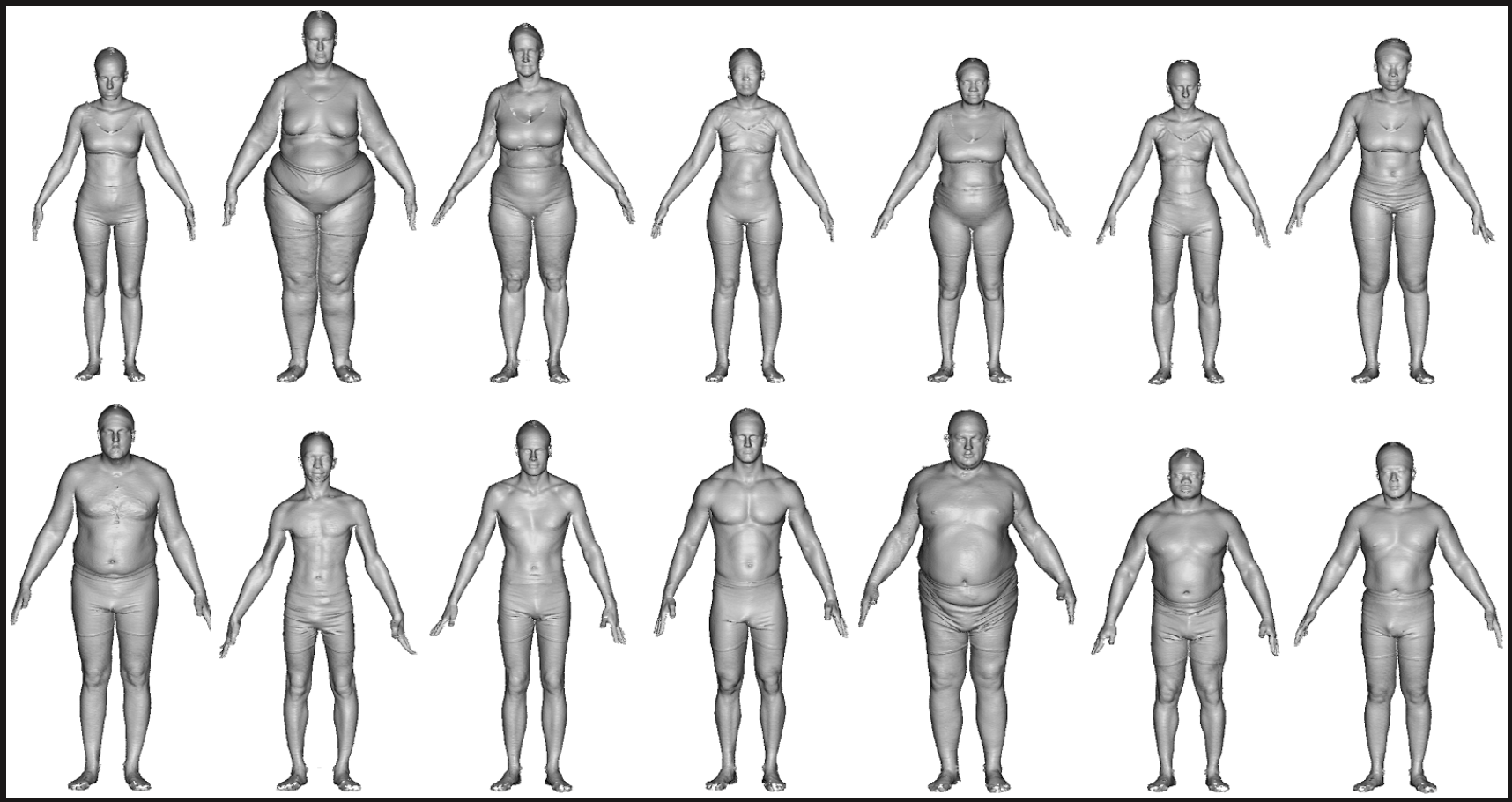
Banana Republic

On-line clothing retail:

- Arbitrary 3D body shape
- Best size that fits

“Over a third of consumers have bought some of their clothes over the internet in the last year…” – http://fashion.telegraph.co.uk

Problem : Body shape variations



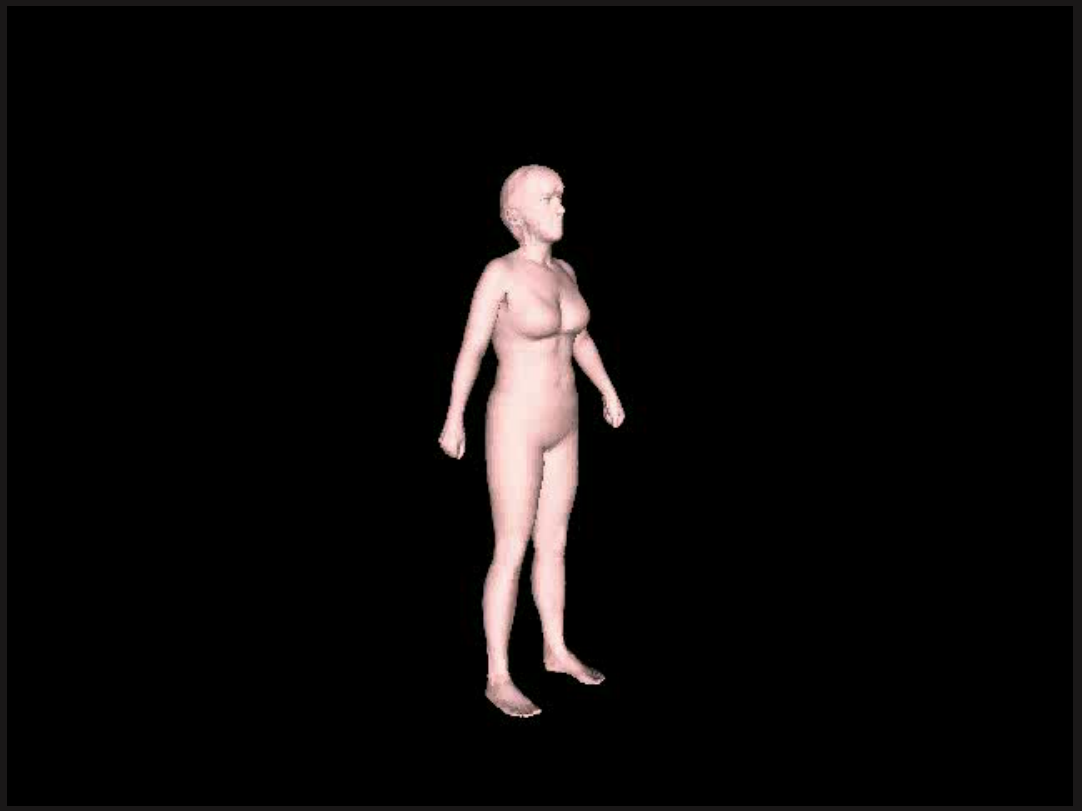
CAESAR Database. Robinette et al. 1999

Approach

1. Use a parametric model of body shape and pose (SCAPE)

Pose (40 dim): θ Joint rotations

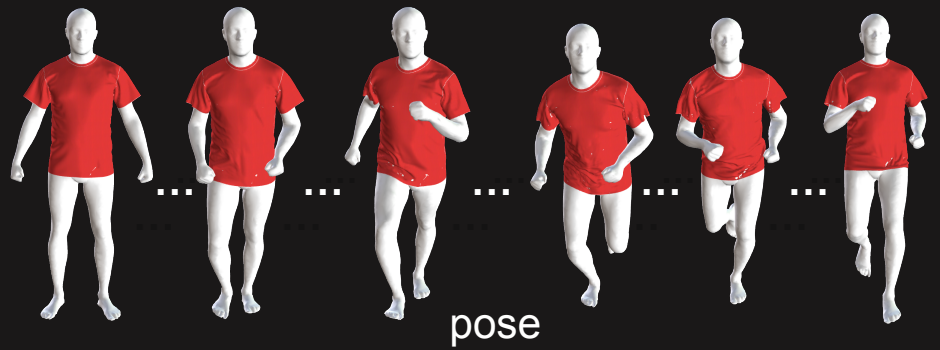
Shape (20 dim): β PCA coefficients



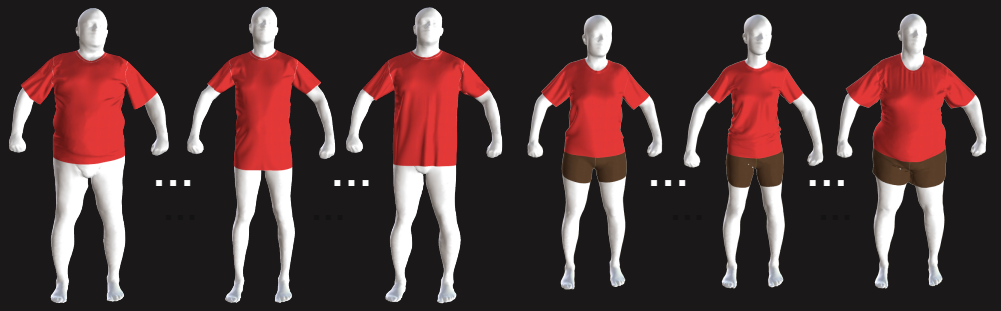
cf . D. Anguelov et al. SIGGRAPH 2005

Approach

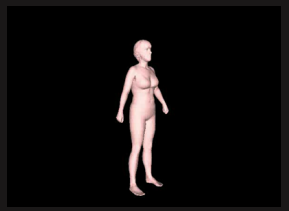
2. Dress training bodies



pose



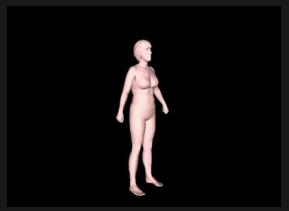
shape

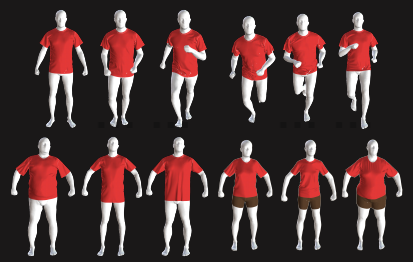


Approach

3. Learn a mapping from body shape to clothing shape

$$\left[\;\;\right] = W \cdot \left[\;\;\right]$$

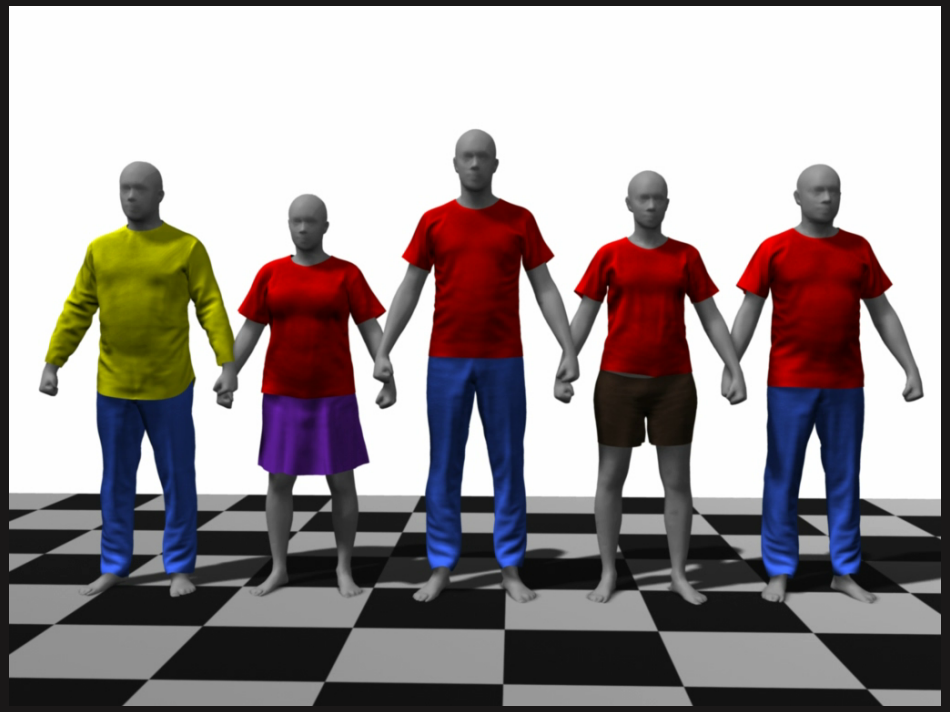


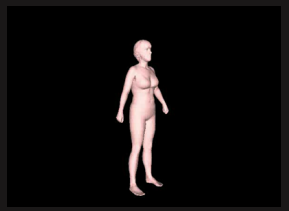


Approach

4. Learn second order cloth dynamics to realistically represent detailed wrinkles

E.D. Aguiar et al. SIGGRAPH 2010

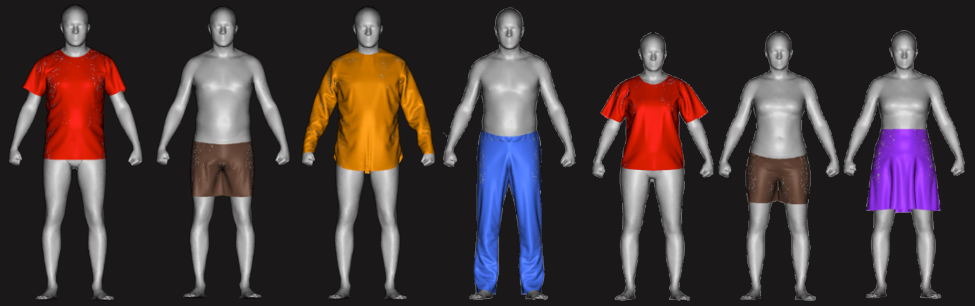




$$\left[\quad\right] = W \cdot \left[\quad\right]$$

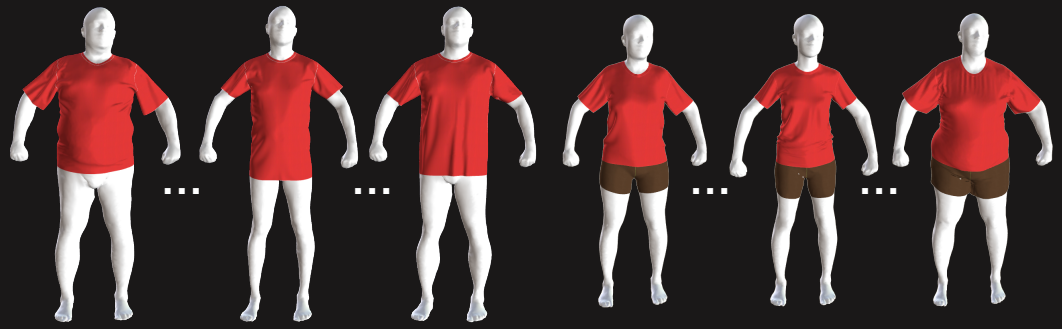
DRAPE : Training data generated by physical simulation

Clothing types

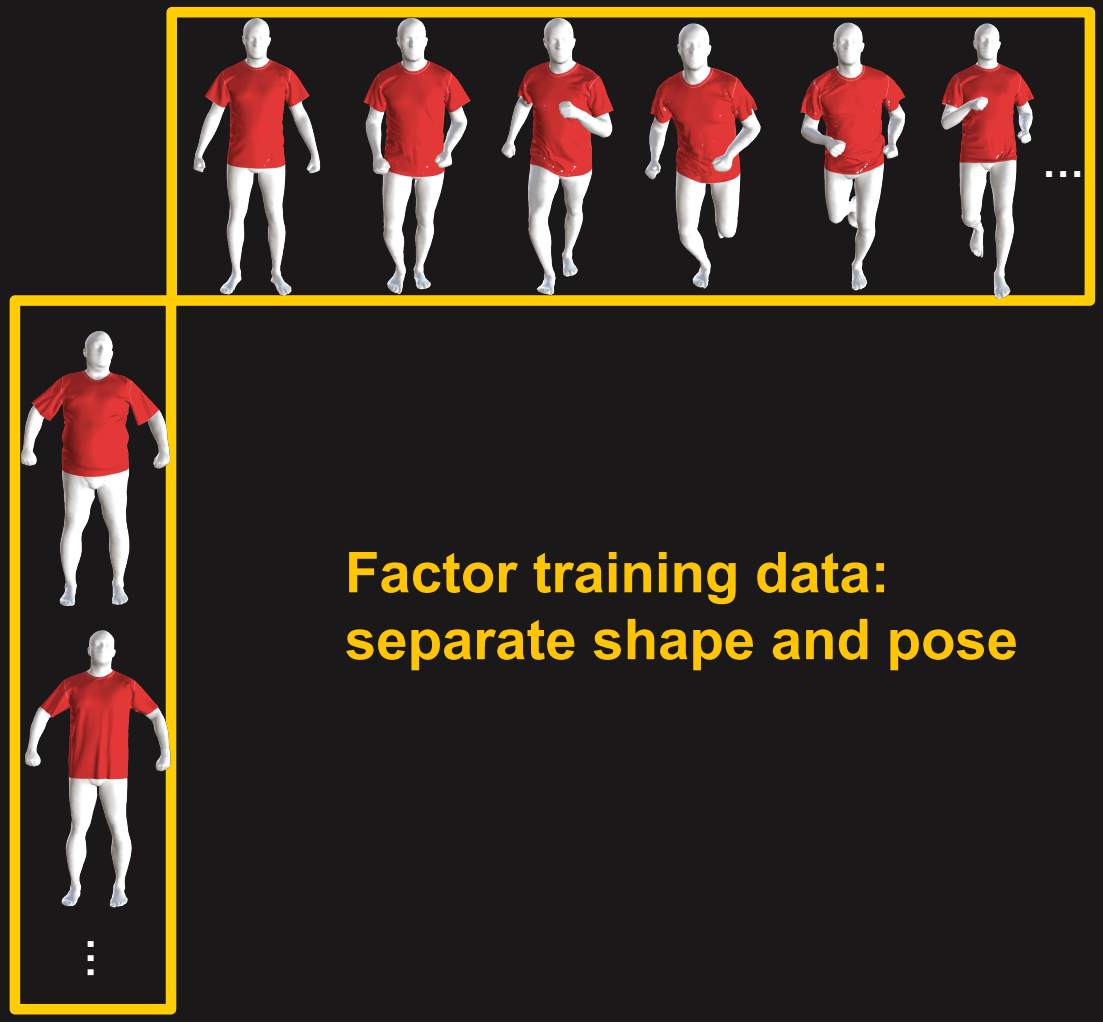


One shape,
many poses

One pose,
many shapes



Learning from physics-based simulation



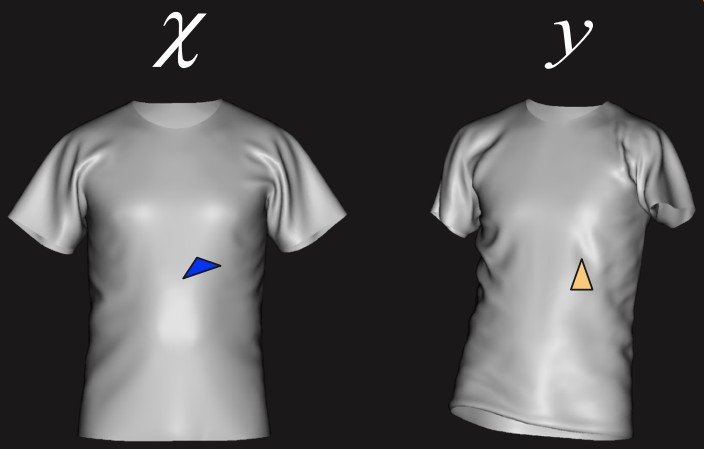
Factor training data:
separate shape and pose

Key idea:
Factoring

Learning from physics-based simulation

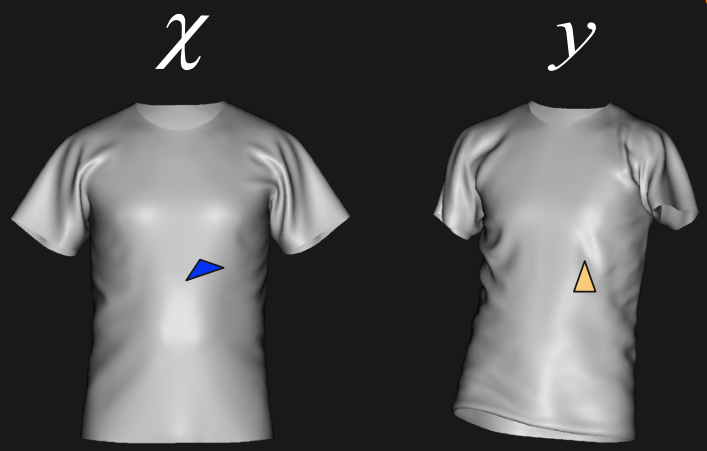
Key idea:
Factoring

Deformation gradient (Sumner and Popović, SIGGRAPH 2004)



T triangles, V vertices

Deformation gradient (Sumner and Popović, SIGGRAPH 2004)



T triangles, V vertices

$$\begin{bmatrix} ? & ? & ? \\ ? & ? & ? \\ ? & ? & ? \end{bmatrix}$$

$$A_t \cdot \blacktriangle_t = \blacktriangle_t$$

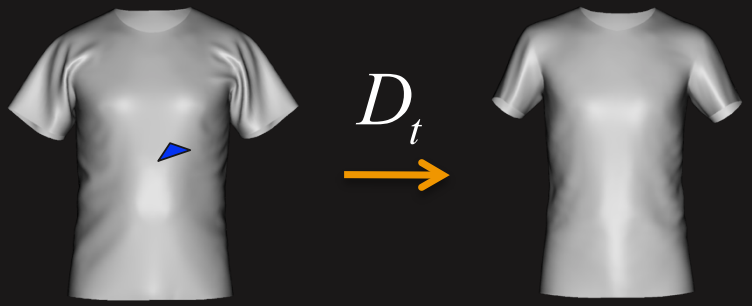
$t \in [1, T]$

Compute A_t from x and y

DRAPE is about modeling A_t

Factored model

change identity



template

shape deformation

$$A_t = D_t \qquad (t \in [1..T])$$

Factored model

change identity

change pose

template

shape deformation

rigid rotation

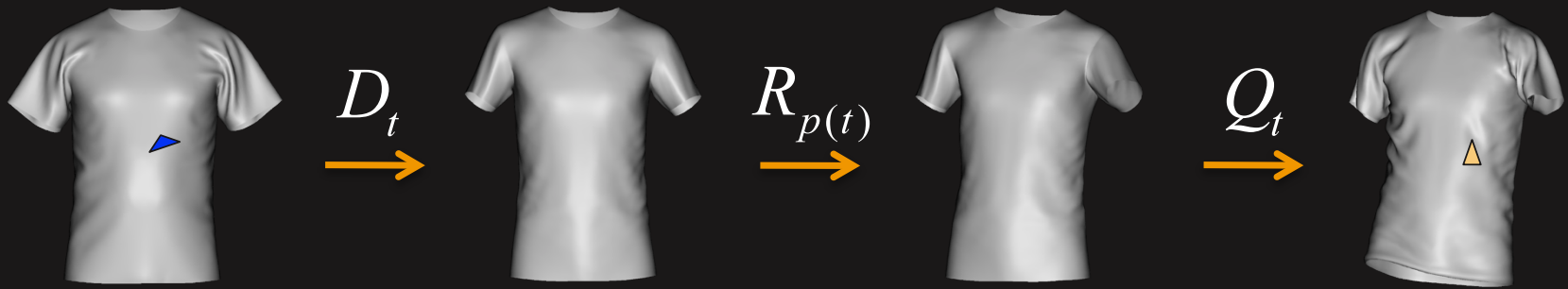
$$A_t = R_{p(t)} \cdot D_t \qquad (t \in [1..T])$$

Factored model

change identity

change pose

add wrinkles, etc



template

shape deformation

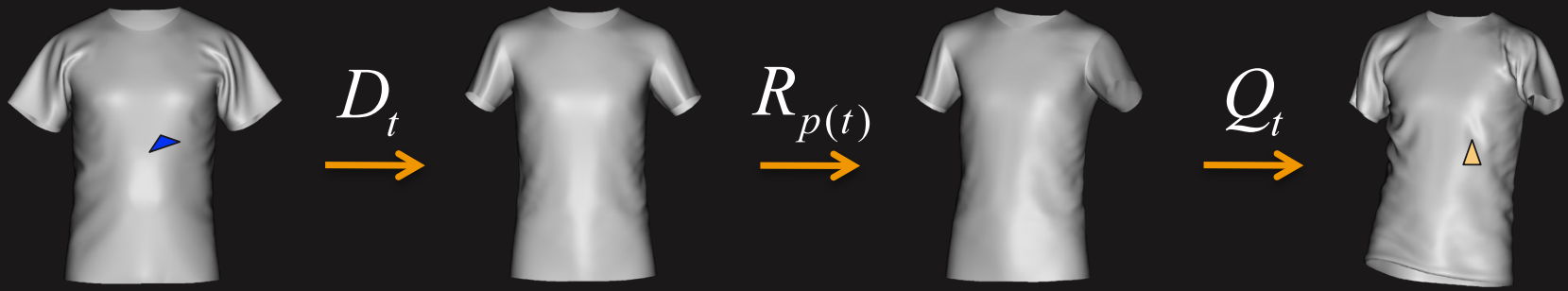
rigid rotation

pose-dependent shape

$$A_t = Q_t \cdot R_{p(t)} \cdot D_t \quad (t \in [1..T])$$

Factored model

change identity | change pose | add wrinkles, etc



template | shape deformation | rigid rotation | pose-dependent shape

$$A_t = Q_t \cdot R_{p(t)} \cdot D_t \quad (t \in [1..T])$$

Learning shape deformation

x

y^j

$y^{|S|}$

$$\begin{bmatrix} ? & ? & ? \\ ? & ? & ? \\ ? & ? & ? \end{bmatrix} \quad D_1^j = A_1^j$$

$$\begin{bmatrix} ? & ? & ? \\ ? & ? & ? \\ ? & ? & ? \end{bmatrix} \quad D_t^j = A_t^j$$

$$\begin{bmatrix} ? & ? & ? \\ ? & ? & ? \\ ? & ? & ? \end{bmatrix} \quad D_T^j = A_T^j$$

$$\begin{bmatrix} & D_1^j & \\ \cdots & D_t^j & \cdots \\ & D_T^j & \end{bmatrix} \in R^{9T \times |S|}$$

Learning shape deformation

$$\begin{bmatrix} & | & D_1^j & \\ \cdot & \vdots & & \\ \cdots & | & D_t^j & \cdots \\ \cdot & \vdots & & \\ & | & D_T^j & \end{bmatrix} \in R^{9T \times |S|}$$

$$\vec{d}^{\,j}$$

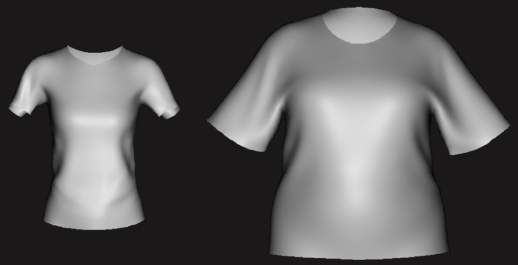
$$S = [\,..\ \vec{d}^{\,j}\ ..]$$

PCA reduce dimensionality:

$$\vec{d} = U_d \cdot \vec{\phi} + \vec{\mu}_d$$

PCA coefficients: $\vec{\phi}$

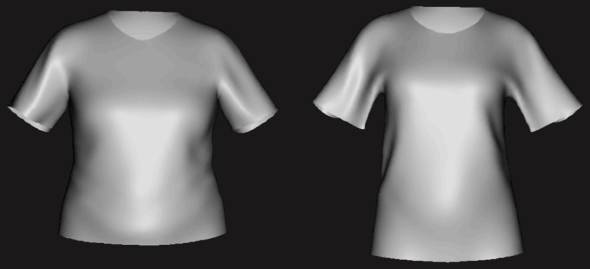
Shape PCA space



PC1 +/- 3std

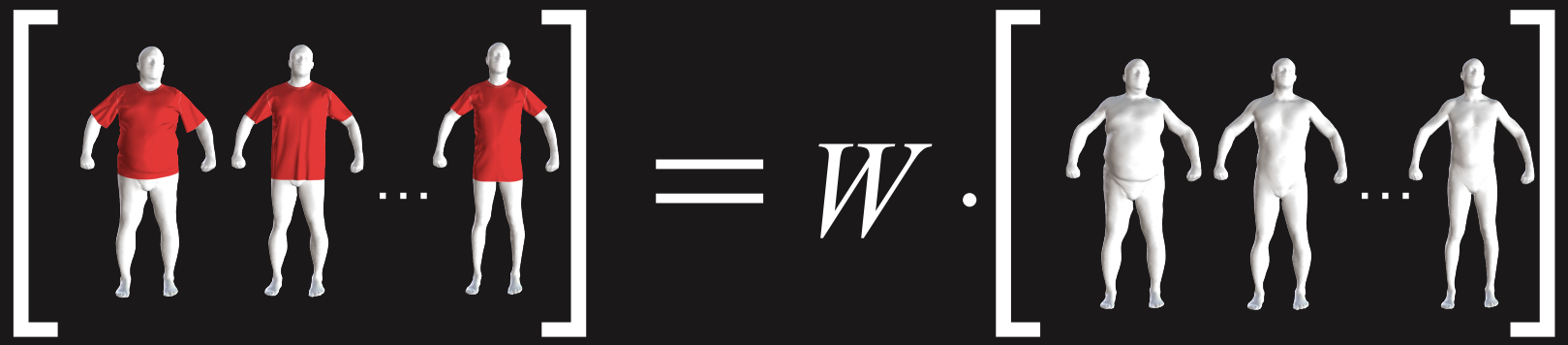
PC2 +/- 3std

mean (female)



PC3 +/- 3std

Adaptation to different body shapes



$$= W \cdot$$

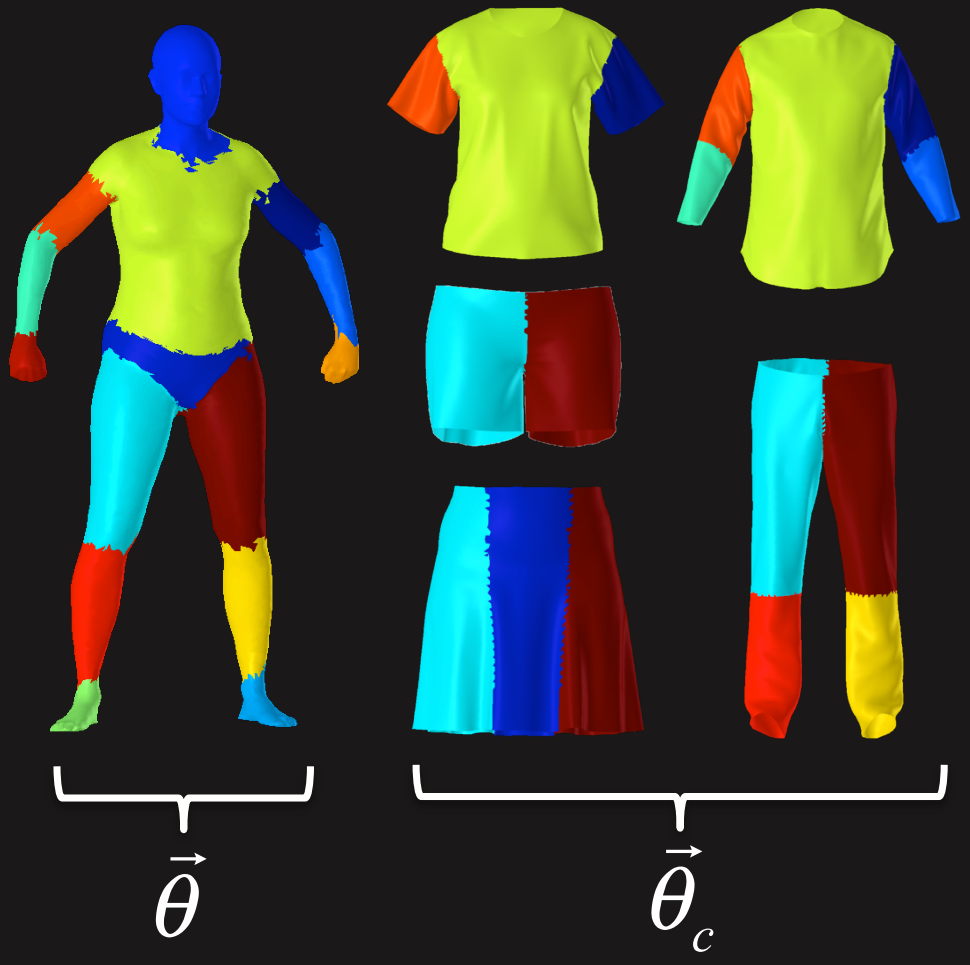
$$[\ldots, \vec{\phi}^{\,j}, \ldots] \qquad [\ldots, \vec{\beta}^{\,j}, \ldots]$$

clothing shape **body shape**

$$W = \arg\min_{W} \left(\sum_{j} \| W \cdot \vec{\beta}^{\,j} - \vec{\phi}^{\,j} \|^2 + \lambda \cdot \| W \|^2 \right)$$

$$\vec{\phi}^{\,*} = W \cdot \vec{\beta}$$

Rigid part rotation



Rigid part rotation of every triangle t in part p

$$R_{p(t)}(\vec{\theta}_c)$$

Learning non-rigid pose-dependant shape deformation

$\chi \quad y^1 \quad \cdots \quad y^i \quad \cdots \quad y^{|P|}$

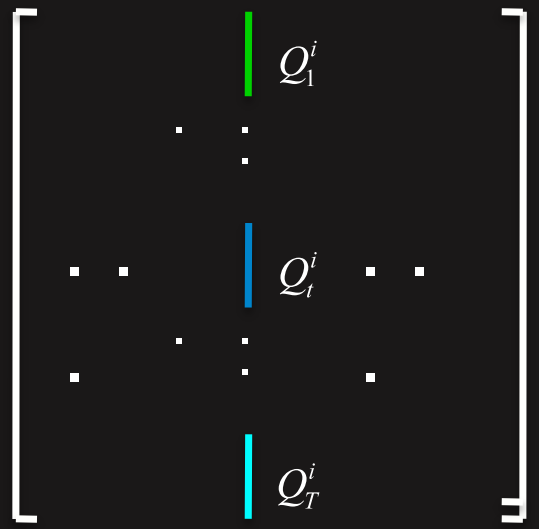
$$\begin{bmatrix} ? & ? & ? \\ ? & ? & ? \\ ? & ? & ? \end{bmatrix} \quad Q_1^i = A_1^i \cdot R_{p(1)}^{i\ -1}$$

$$\begin{bmatrix} ? & ? & ? \\ ? & ? & ? \\ ? & ? & ? \end{bmatrix} \quad Q_t^i = A_t^i \cdot R_{p(t)}^{i\ -1}$$

$$\begin{bmatrix} ? & ? & ? \\ ? & ? & ? \\ ? & ? & ? \end{bmatrix} \quad Q_T^i = A_T^i \cdot R_{p(T)}^{i\ -1}$$

$$\begin{bmatrix} & Q_1^i & \\ & \vdots & \\ \cdots & Q_t^i & \cdots \\ & \vdots & \\ & Q_T^i & \end{bmatrix} \in R^{9T \times |S|}$$

Learning non-rigid pose-dependent deformation



$$\in R^{9T \times |S|}$$

$$\vec{q}^{\,j}$$

$$P = [.. \ \vec{q}^{\,j} \ ..]$$

PCA reduce dimensionality:

$$\vec{q} = U_q \cdot \vec{\psi} + \vec{\mu}_q$$

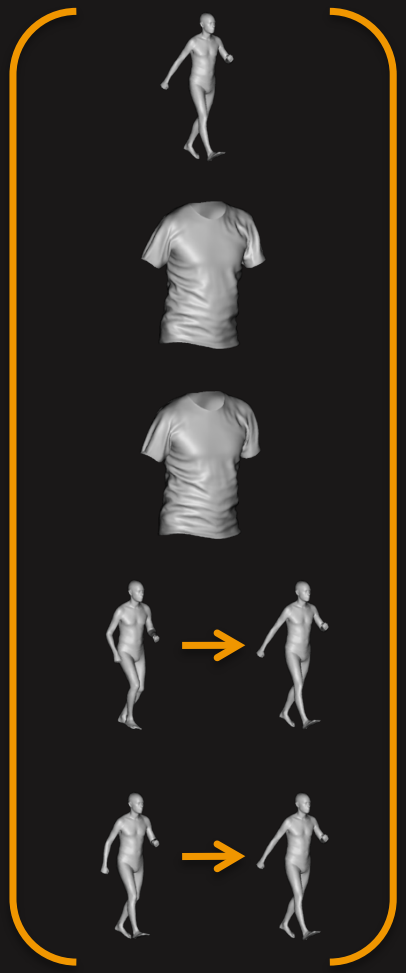
PCA coefficients: $\vec{\psi}$

Second order cloth dynamics (E.D. Aguiar et al. SIGGRAPH 2010)

$\vec{\psi}^{\,f}$

pose-dependent deformation

$$= f(\vec{\Psi}^{\,f}) = f$$



$\vec{\theta}_c^{\,f}$ rigid pose

$\vec{\psi}^{\,f-1}$

$\vec{\psi}^{\,f-2}$

$\vec{z}^{\,f,f-2}$

$\vec{z}^{\,f-1,f-2}$

position
velocity
rotations

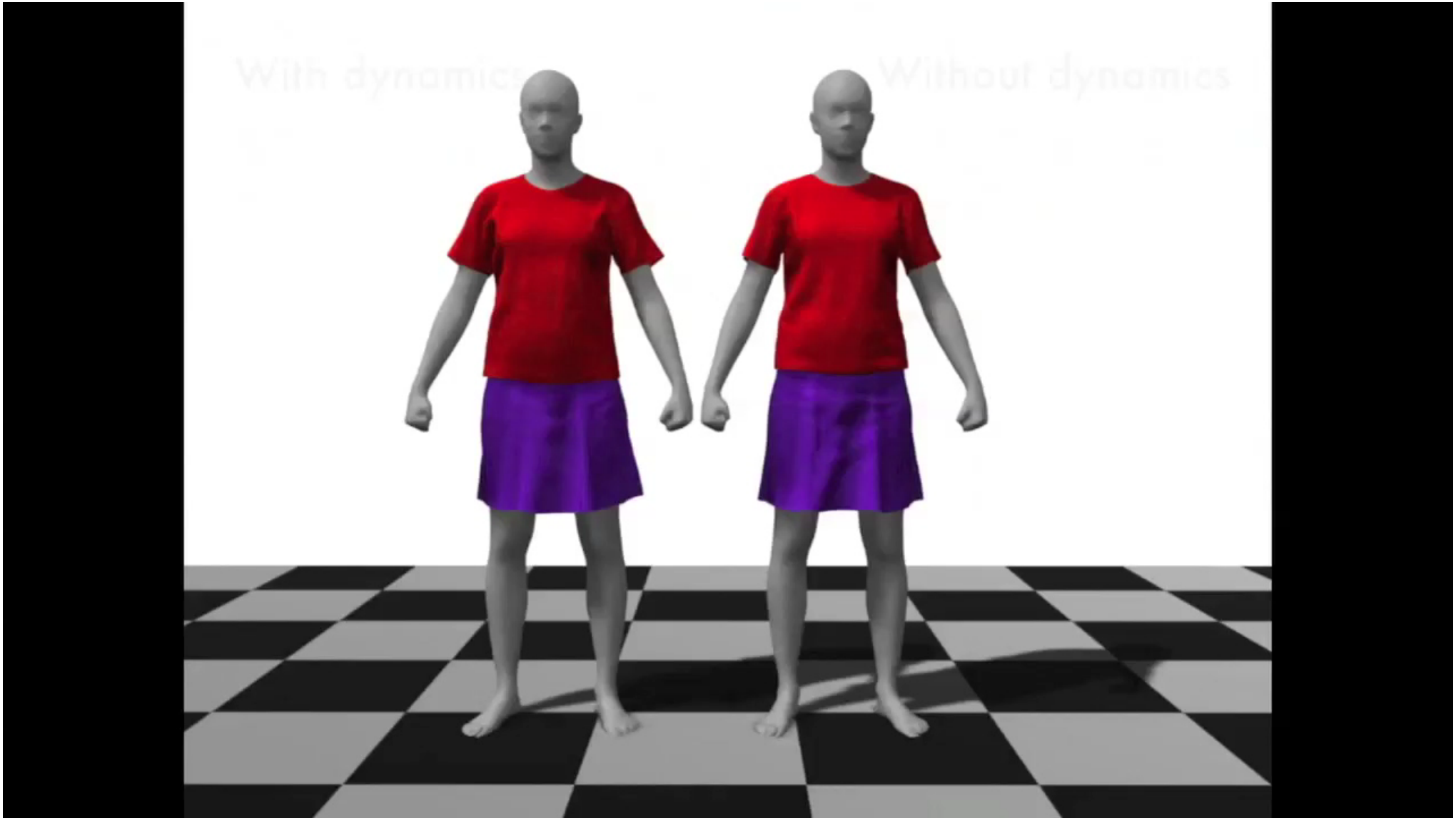
Zero order cloth model (E.D. Aguiar et al. SIGGRAPH 2010)

$\vec{\psi}^{\,f}$

pose dependent deformation

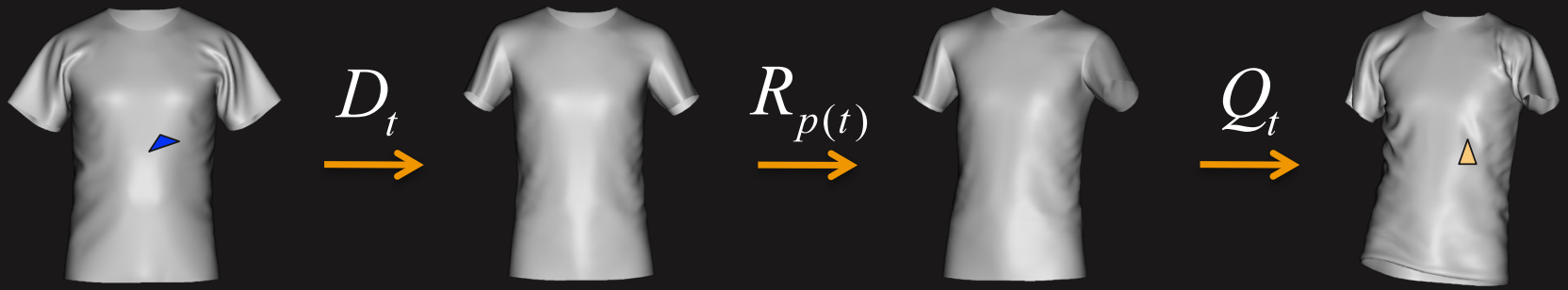
$=$ f $\left(\right.$  $\left. \right)$ $\vec{\theta}_c^{\,f}$

rigid pose


With dynamics
Without dynamics

Deformation process recap

change identity change pose add wrinkles, etc



template shape deformation rigid rotation pose-dependent shape

$$A_t = Q_t(\vec{\Psi}^f) \cdot R_{p(t)}(\vec{\theta}_c^f) \cdot D_t(\vec{\beta})$$

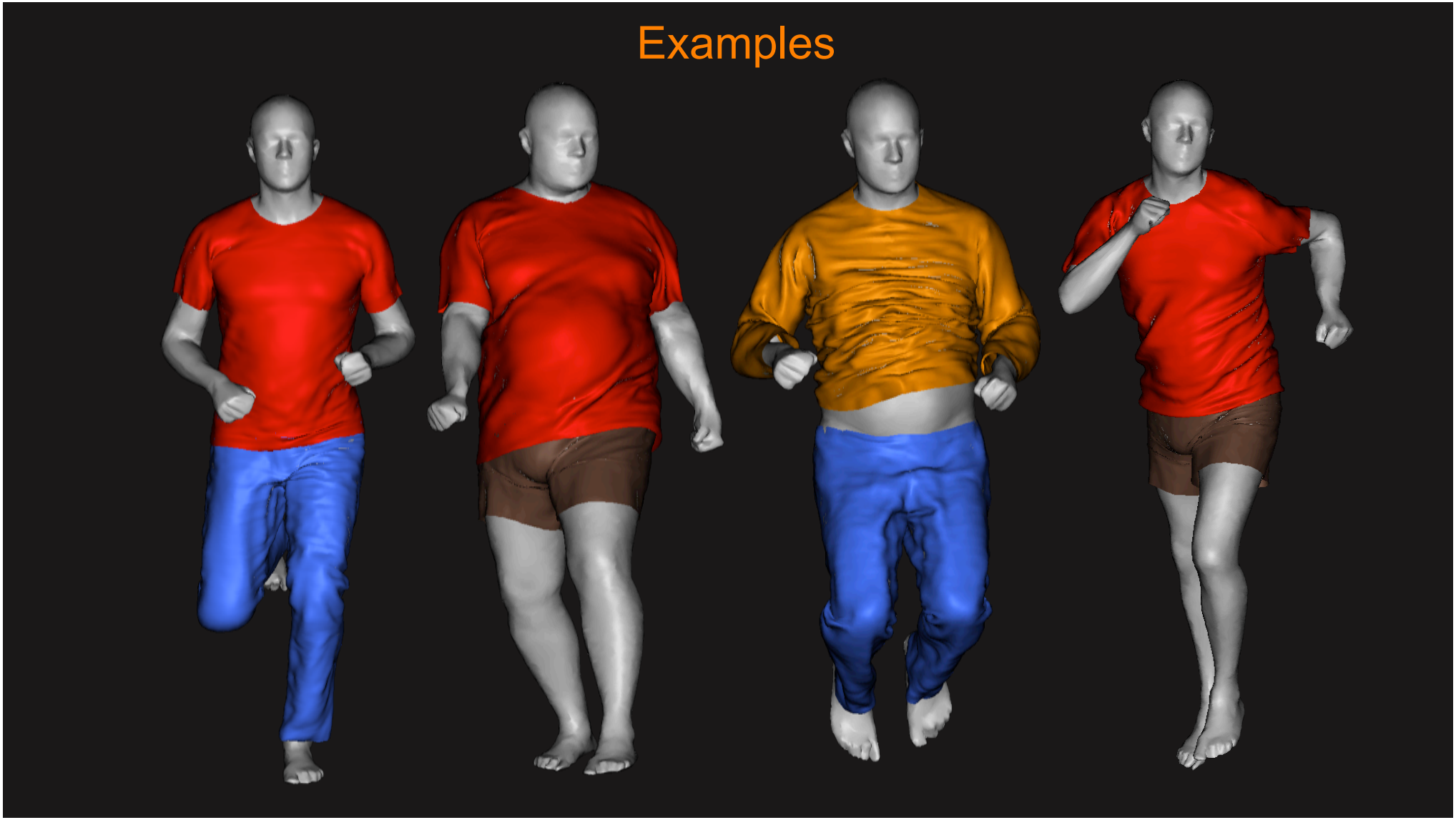
Interpenetration

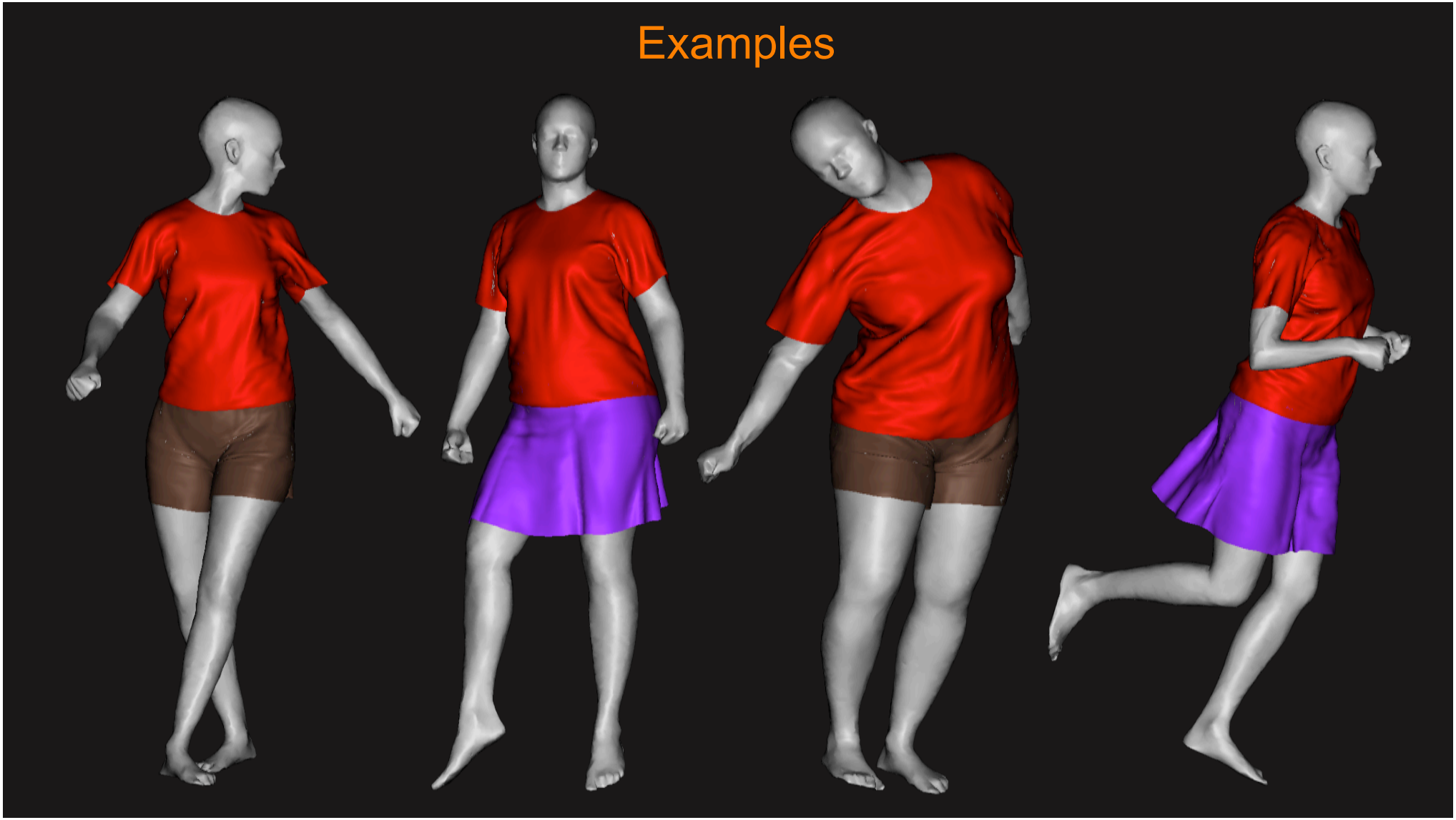
Remove penetration gradually using iterative least squares

initial after 1st iter done

Key : efficiency

Least squares solve with quadratic error function


Examples


Examples

Key performance summary

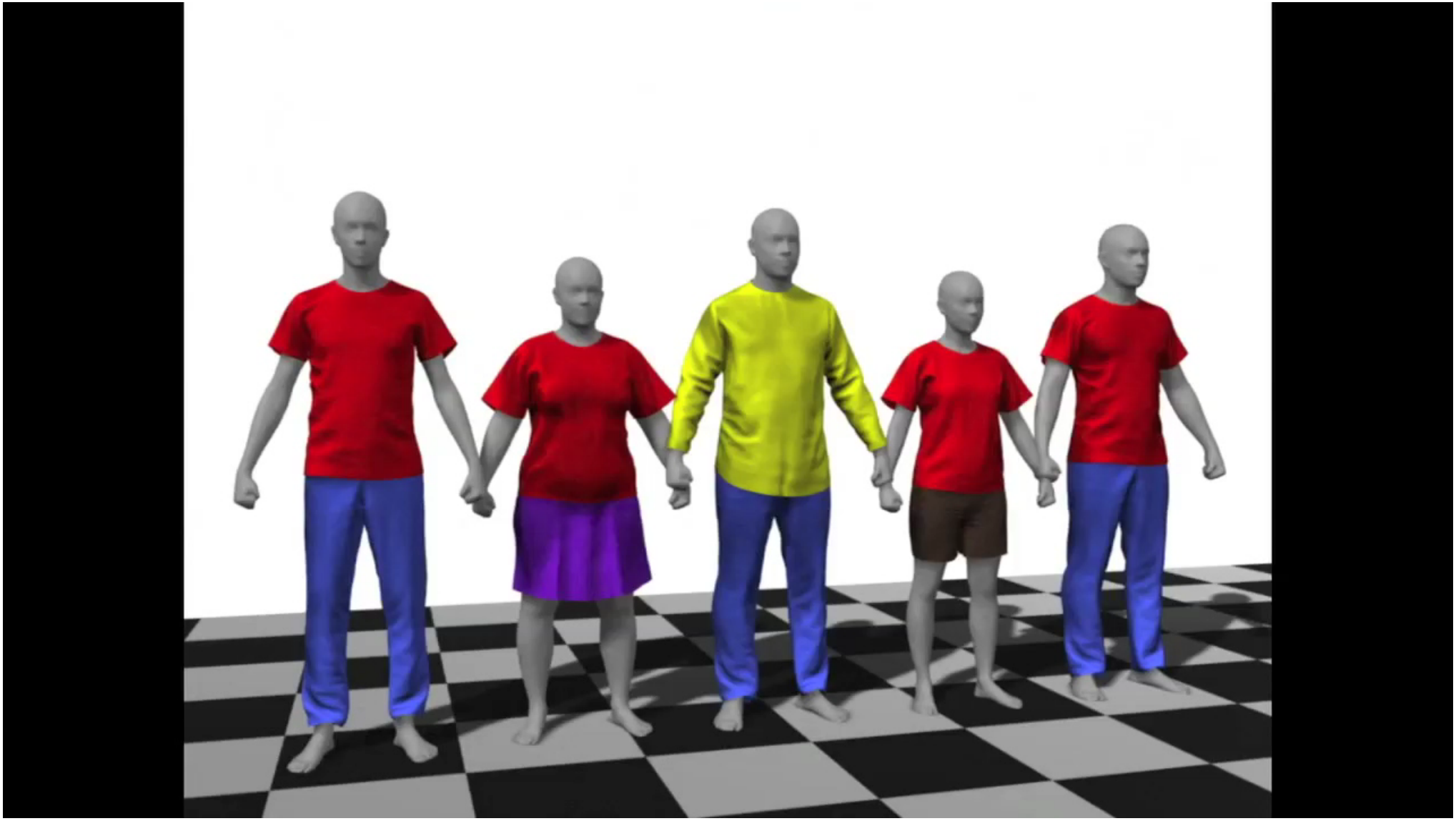
Mesh Resolution: 20-30 K triangles

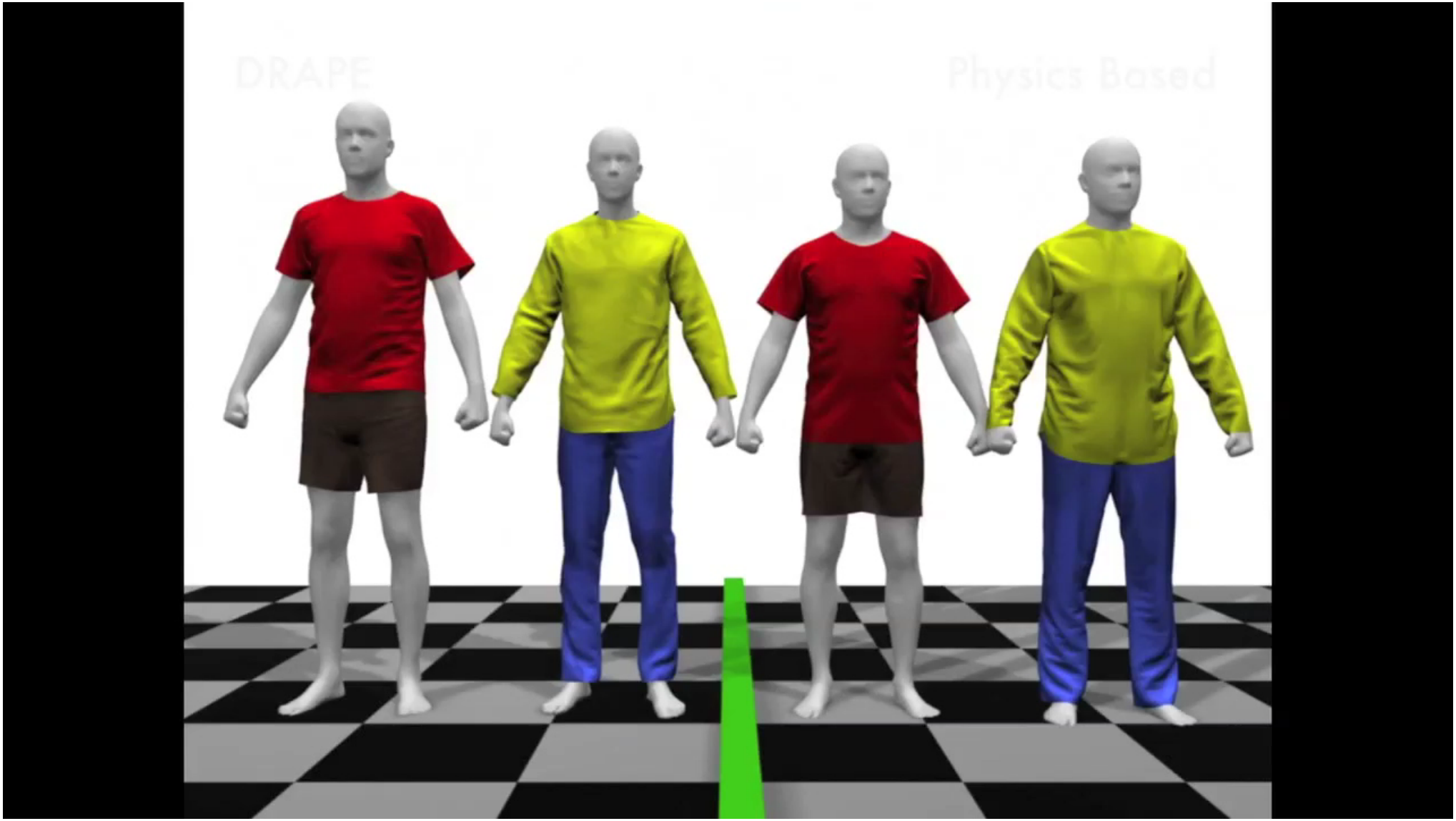
Speed (single frame):

- DRAPE: 0.4 - 0.8 sec/frame — 90 – 190 times faster
- OptiTex: 20 - 60 sec/frame

Speed (in animation):

- DRAPE: 0.4 – 0.8 sec/frame — 7 – 8 times faster
- OptiTex: 2.5 – 6.1 sec/frame





Future work

User preference fit

- User preference (tight or loose)
- Model adaption to the user input
- Requires more training data

DRAPE as initialization for physical simulation

- Use DRAPE to automatically predict initial clothing

Multi-linear clothing model

- Pose-dependent deformation also as a function of body shape
- Requires more training data

Make the custom clothing

DRAPE. Clothes that fit.

Fact sheet

Authors

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Michael J. Black, MPI-IS and Brown

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