# Sensitivity-optimized Rigging for Example-based Real-time Clothing Synthesis


(*=joint 1st authors)

Weiwei Xu*
Nobuyuki Umentani*
Qianwen Chao
Jie Mao
Xiaogang Jin
Xin Tong

# Motivation

- Fast clothing synthesis for interactive application


[Winning Eleven 2014]


[Assassins Creed]

# Key Assumption: Pose-to-Clothing Mapping

tight

our interest

loose

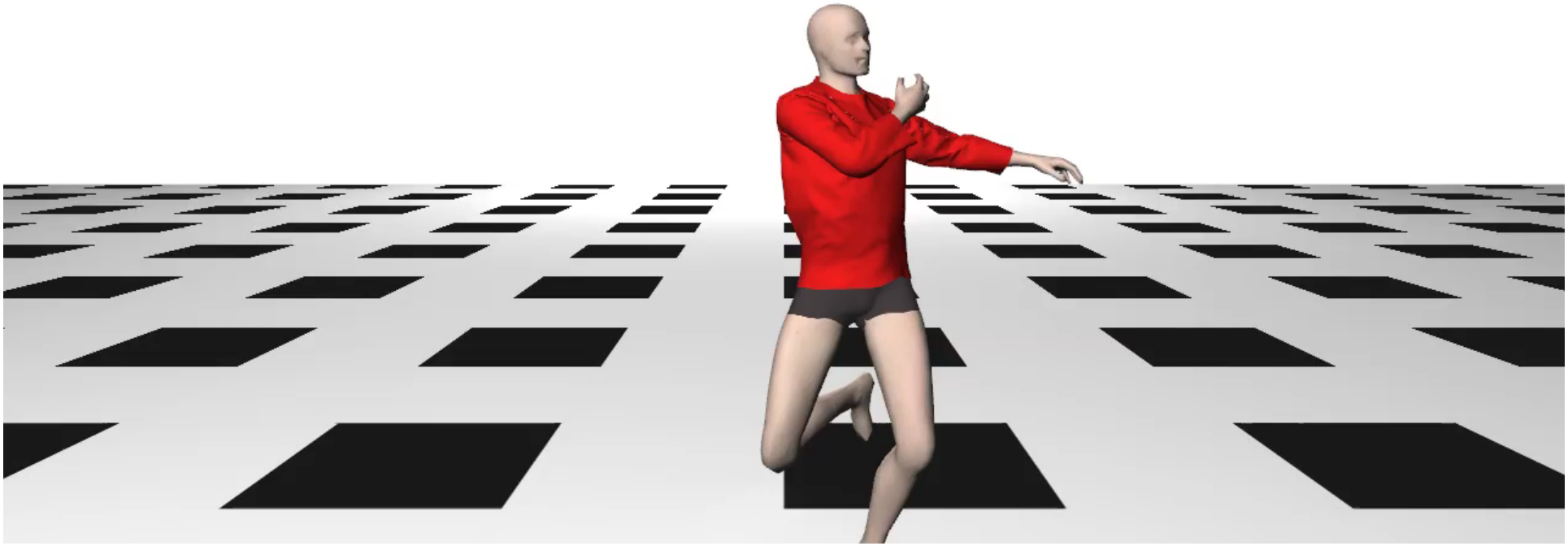
# Example-based Clothing Synthesis

Input: body pose
(i.e. joint rotations)

Database

Output: clothing
(i.e. vertex positions)

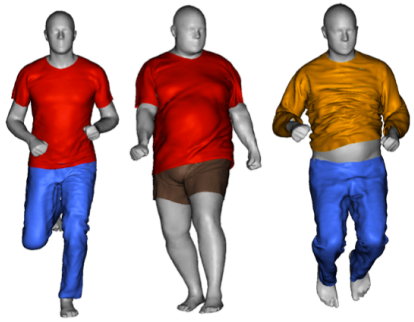
# CPU Implementation 60FPS



# CPU+GPU 200 Characters 20FPS

# Related Works: Example-based Clothing

[de Aguiar et al. 2010]

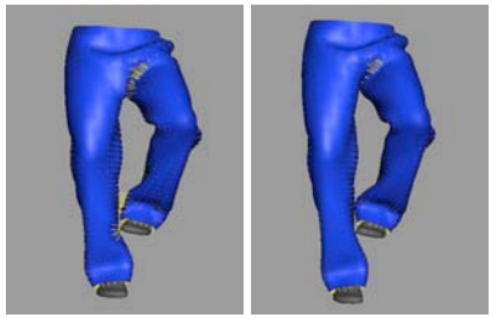


[Peng et al. 2010]

[Wang et al. 2010]

[Kavan et al. 2010]

[Wang et al. 2013]

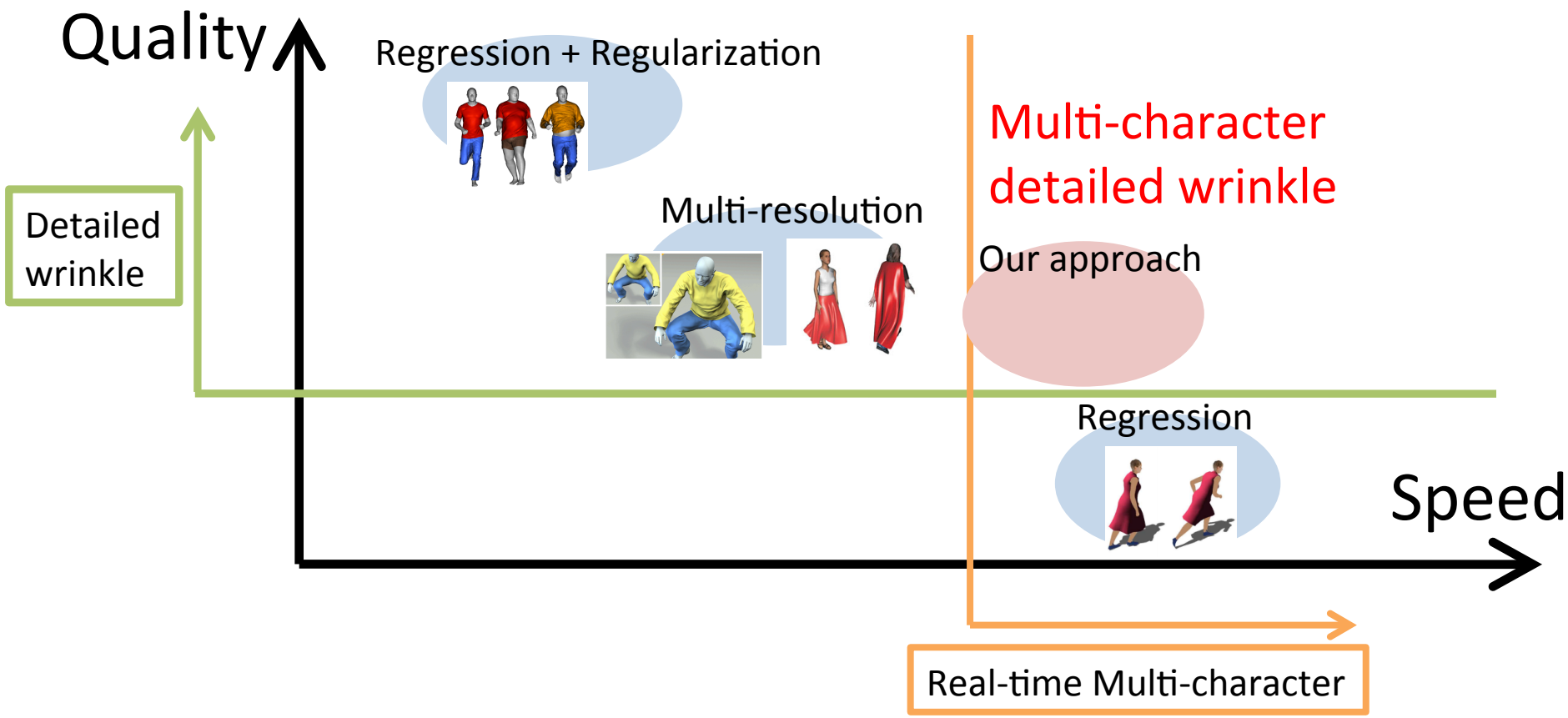


[Kim et al. 2008]

[Feng et al. 2010]

[Hahn et al. 2014]

# State of the Art (quality vs. speed)



# Our Approach: Rigged Clothing

We use Linear Blend Skinning for clothing

Deformed vertex po | Bone weight | ial vertex position | ation

Body rigging

$$x = \sum_b w_b \left( \mathbf{R}_b x_0 + \mathbf{T}_b \right)$$

Bone rotation

Bone translation

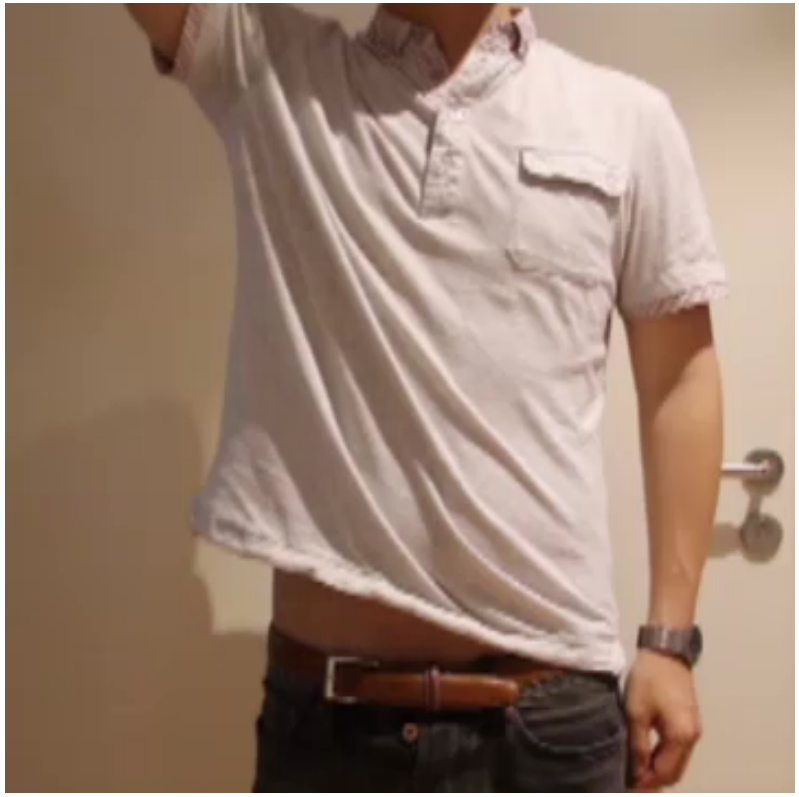
cloth rigging

$$y = \sum_b w_b \left( \mathbf{R}_b \; y_0 + \mathbf{T}_b \right)$$

?

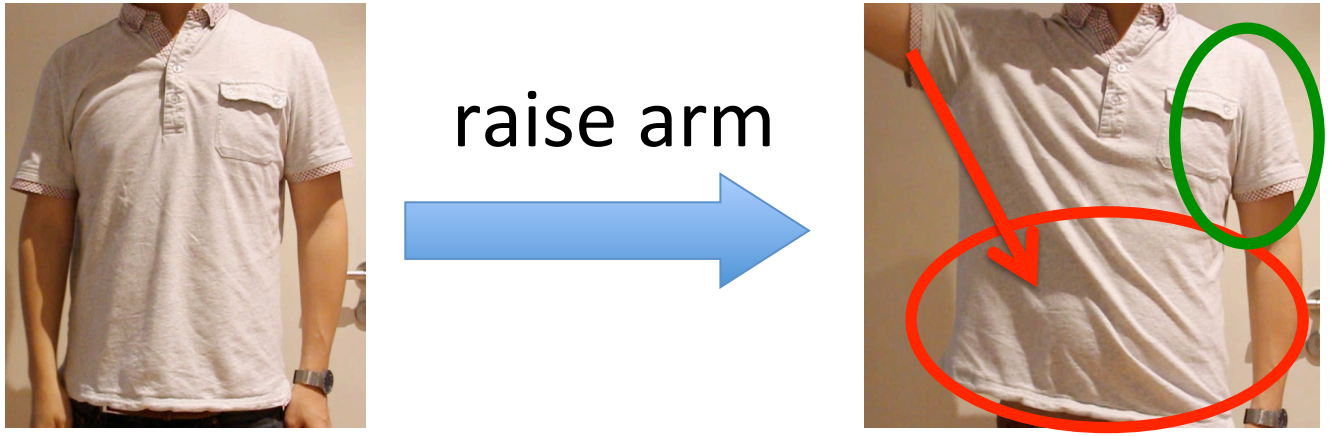
# Challenges for Rigged Clothing

- Clothing move differently from body forming wrinkle



# Dividing Clothing Into Parts

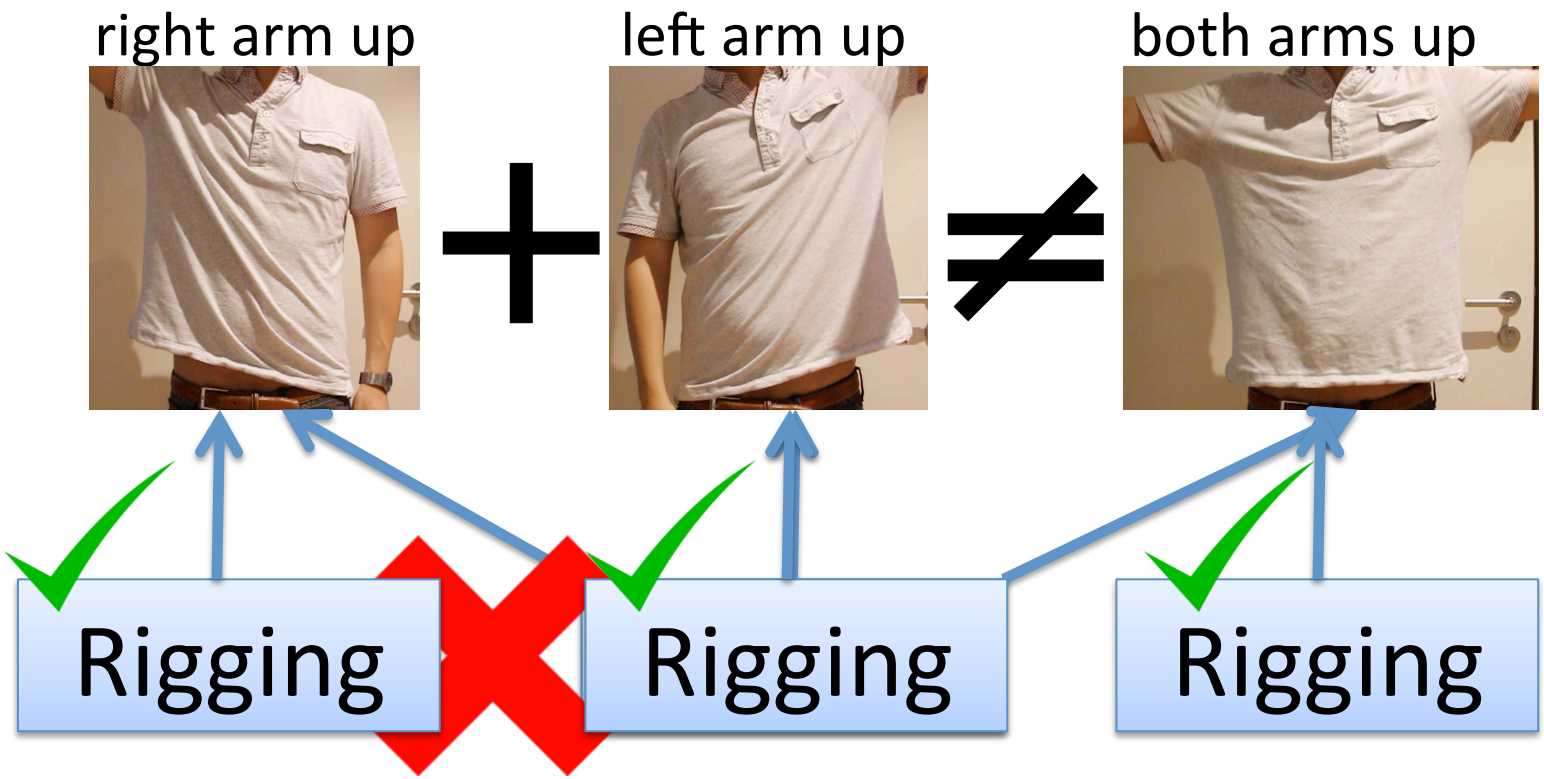
- Global joint-clothing influence
- Locality of the clothing wrinkle




partition

# Multi-prediction approach

- Clothing deformation is very nonlinear



# Our Approach: Rigged Clothing

We use Linear Blend Skinning for clothing

Body rigging

$$x = \sum_b w_b \left( \mathbf{R}_b x_0 + \mathbf{T}_b \right)$$

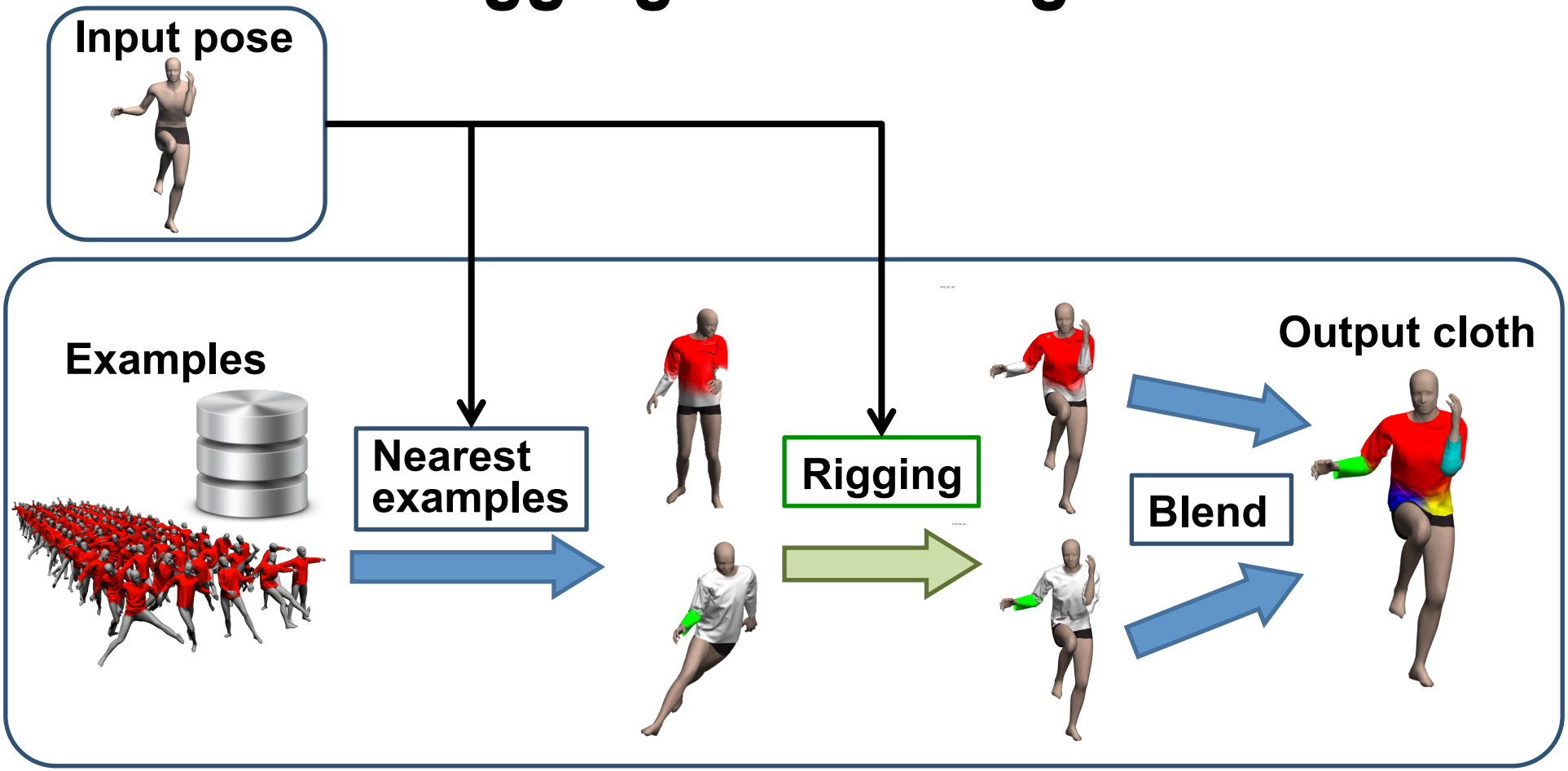
Global influence

Near example

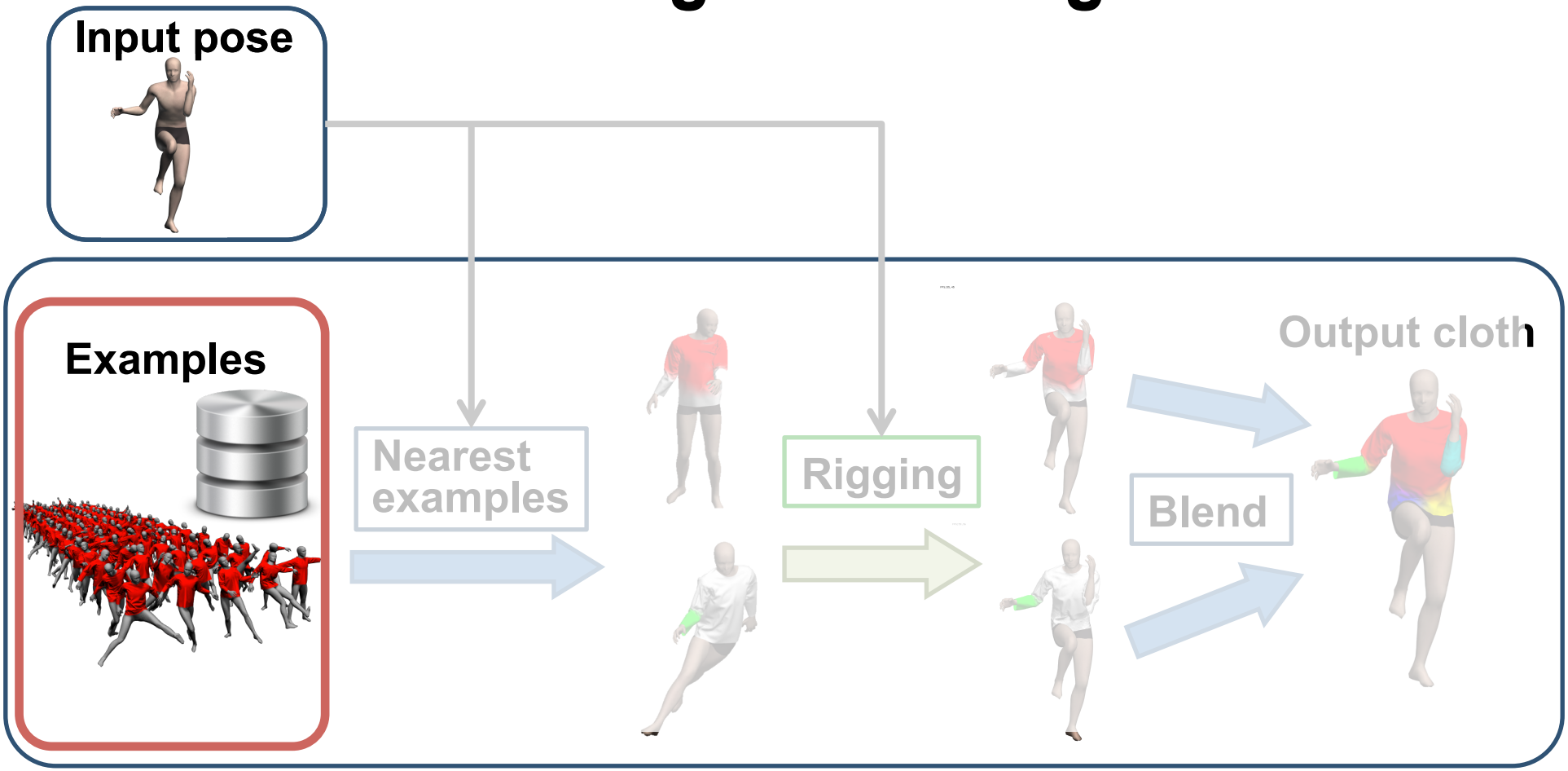
cloth rigging

$$y = \sum_b w_b \left( \mathbf{R}_b y_e + \mathbf{T}_b \right)$$

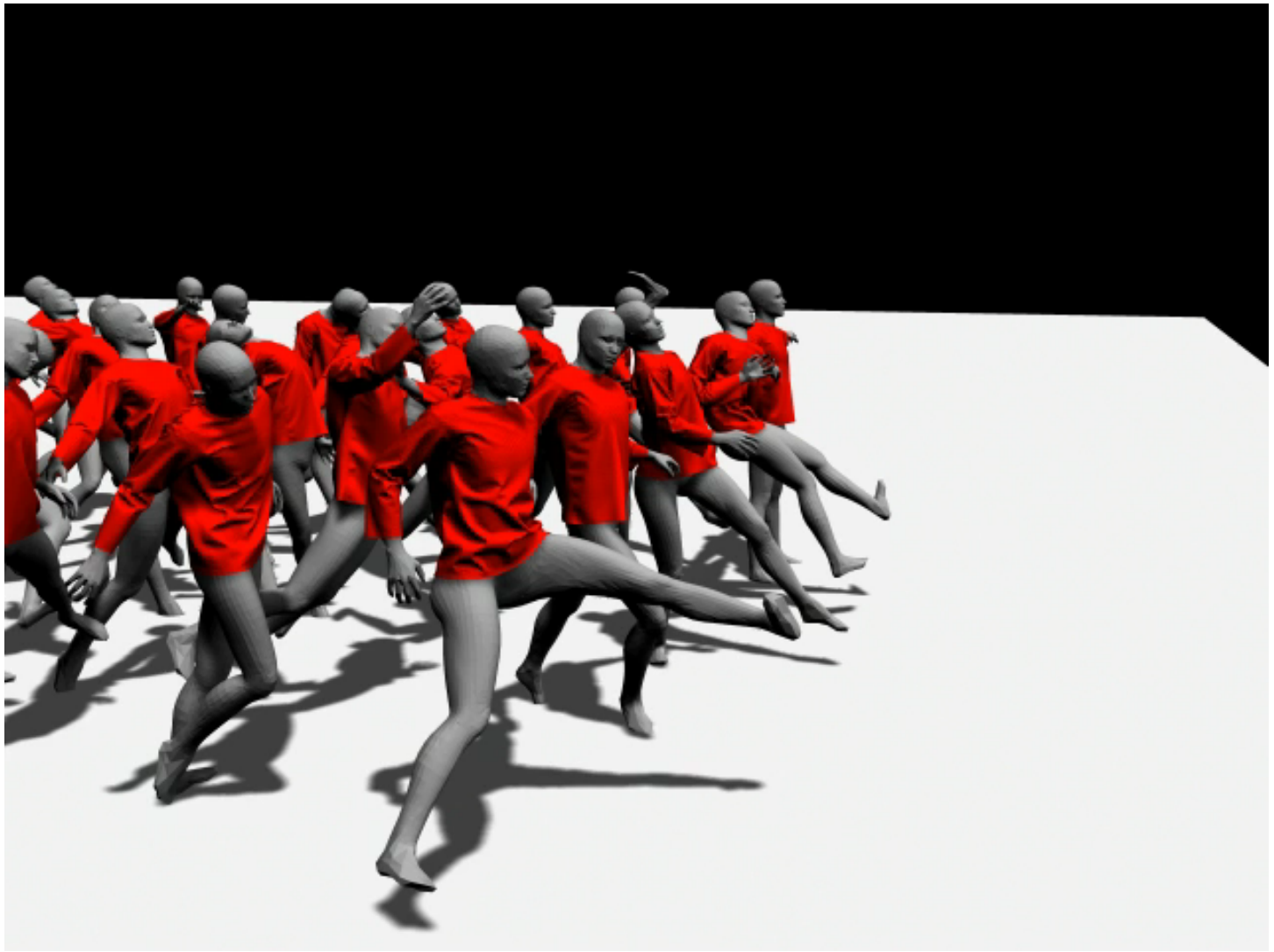
# Procedure: Rigging & Blending



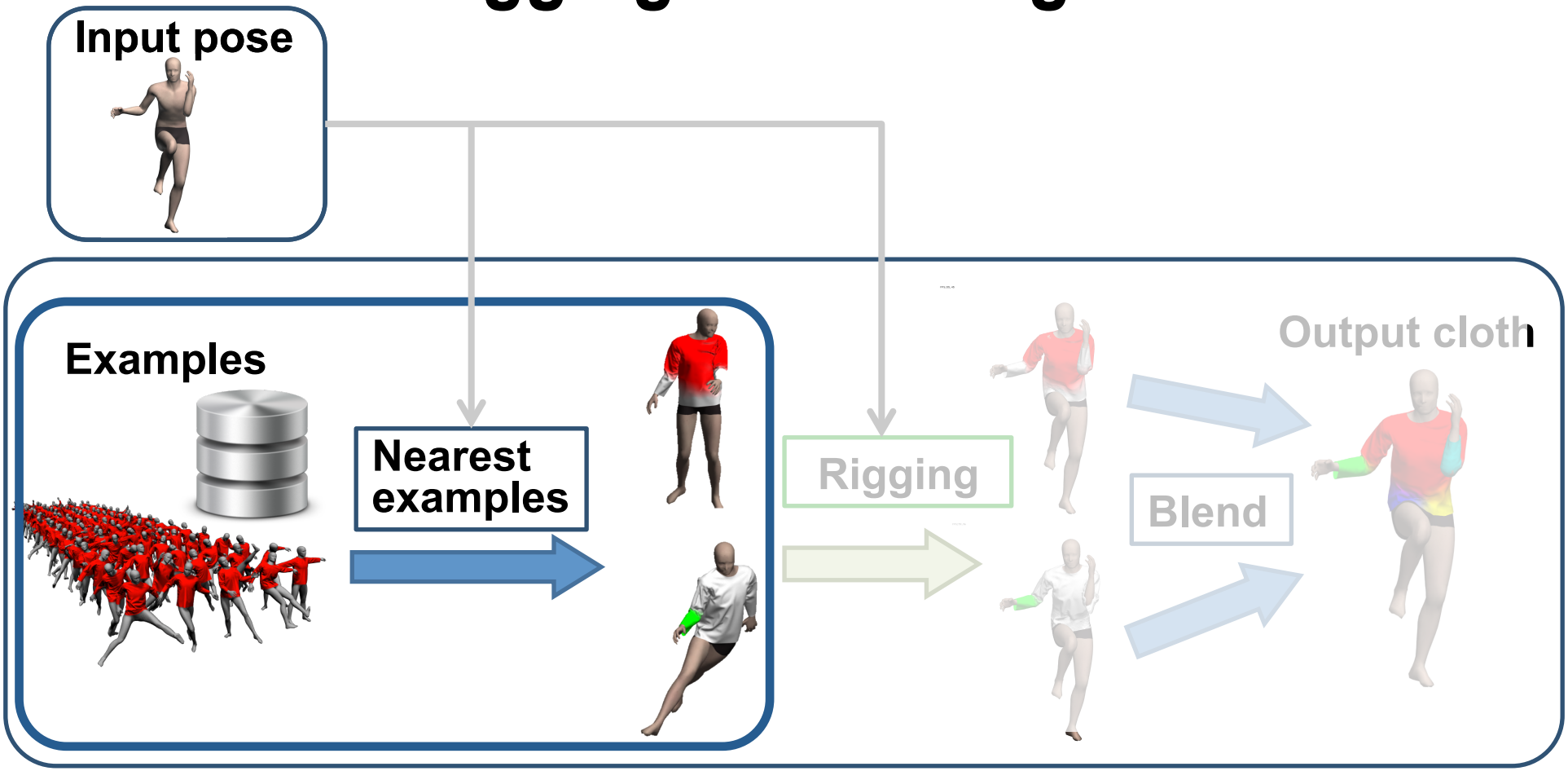
# Procedure: Skinning & Blending



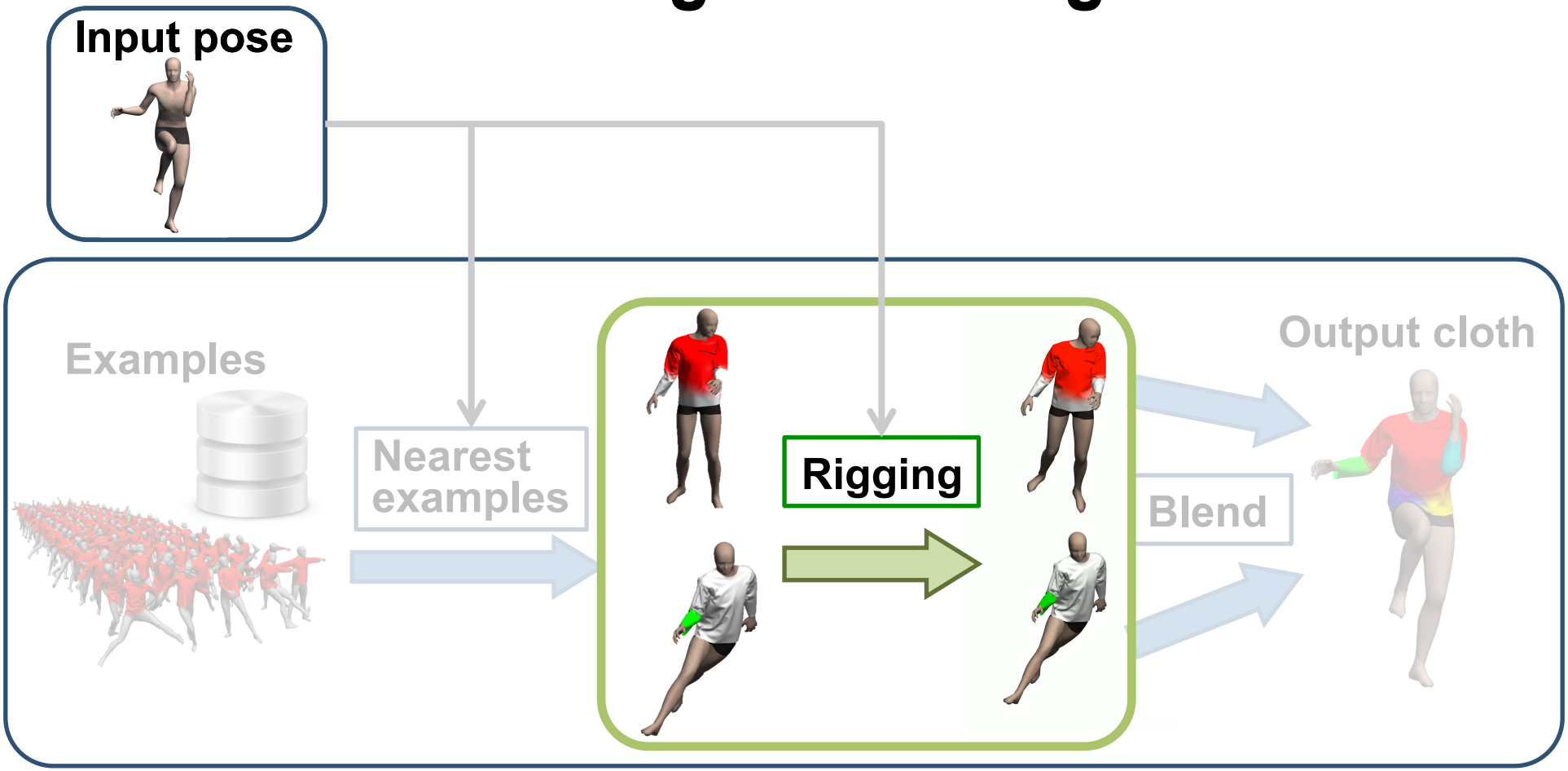
# Database: Example Poses & Clothing



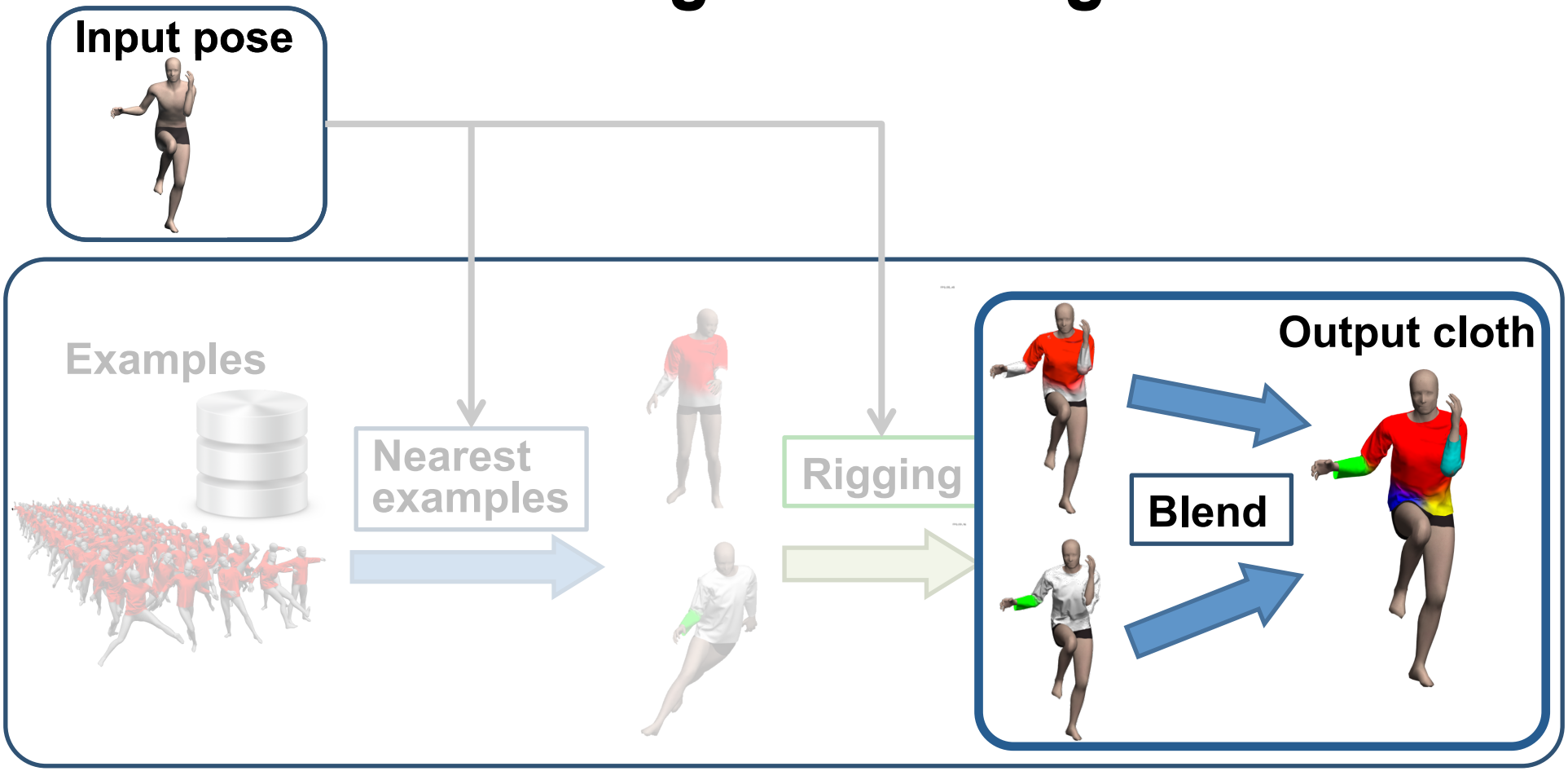
# Procedure: Rigging & Blending



# Procedure: Skinning & Blending



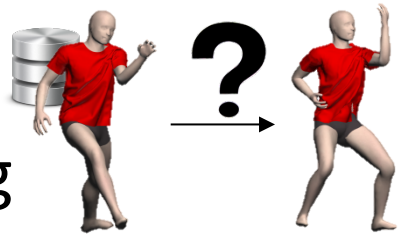
# Procedure: Skinning & Blending



# Contributions

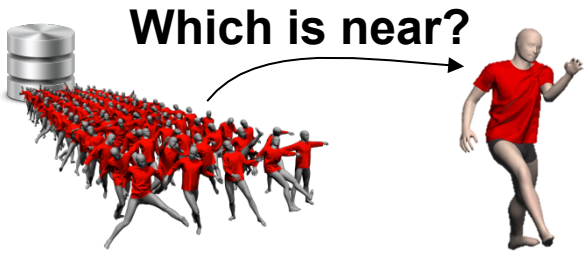
Examples' rigging model

→ Sensitivity-optimized rigging




Find nearest examples to

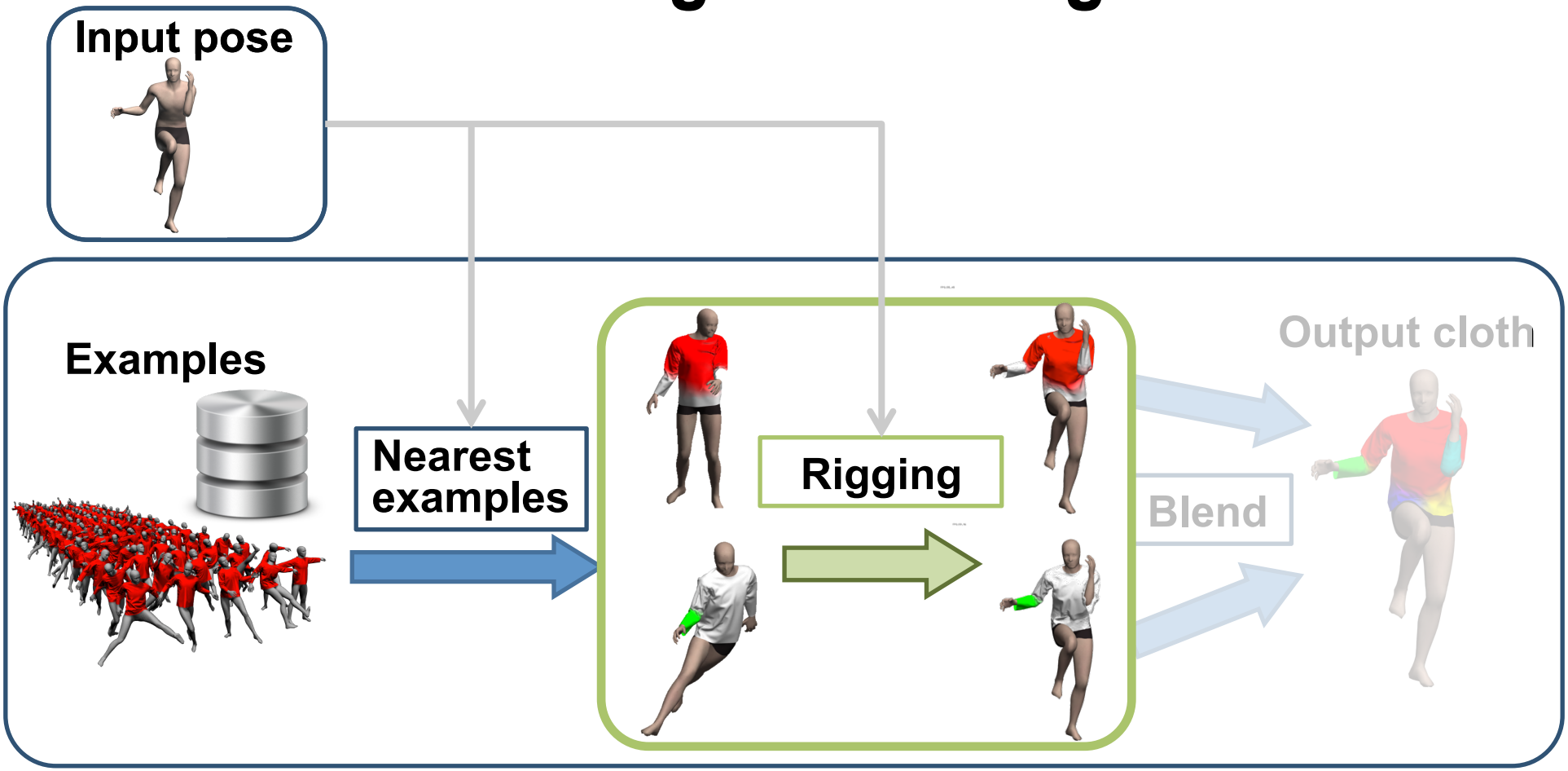
→ Sensitivity distance measure



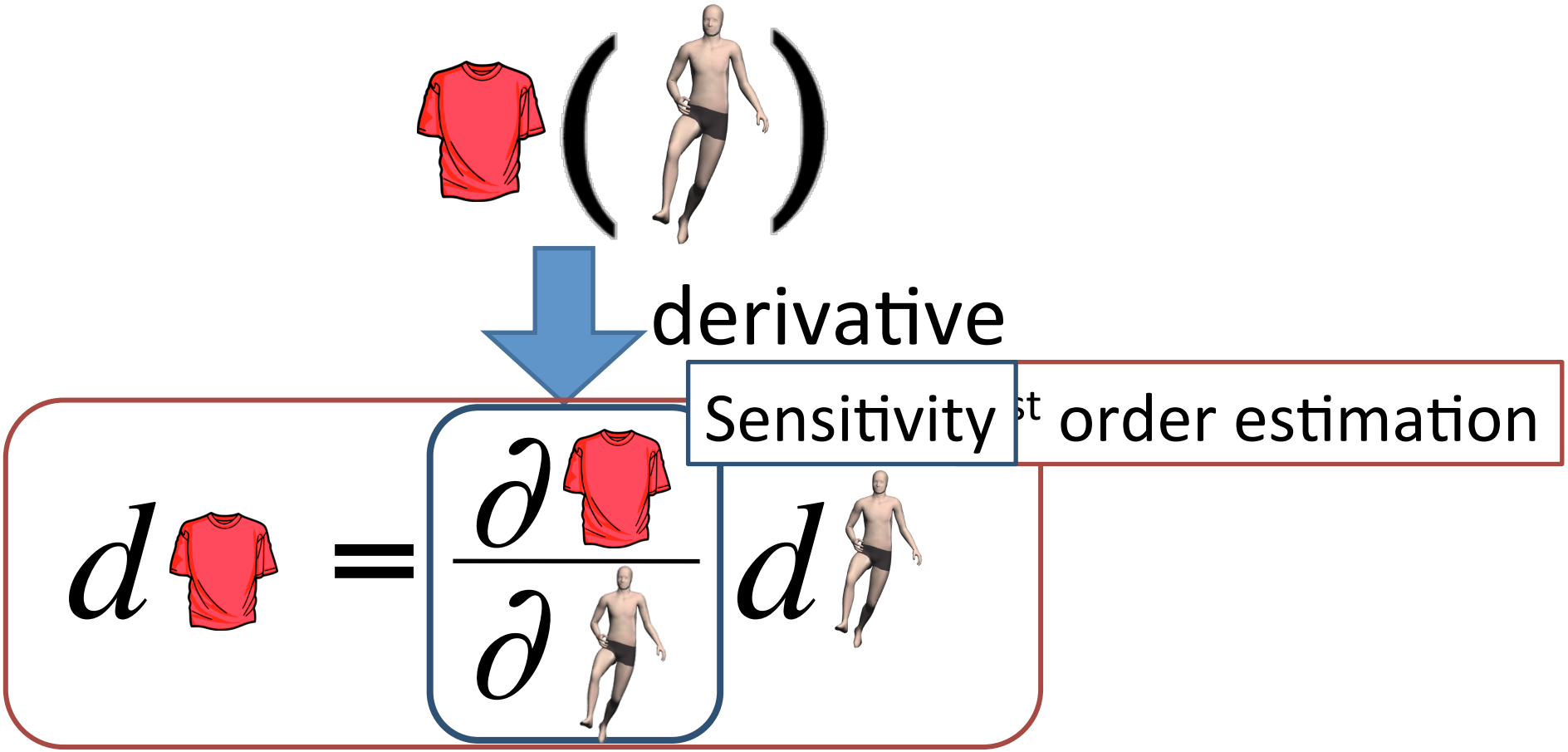

Determine example poses

→ MCMC approach

# Procedure: Skinning & Blending

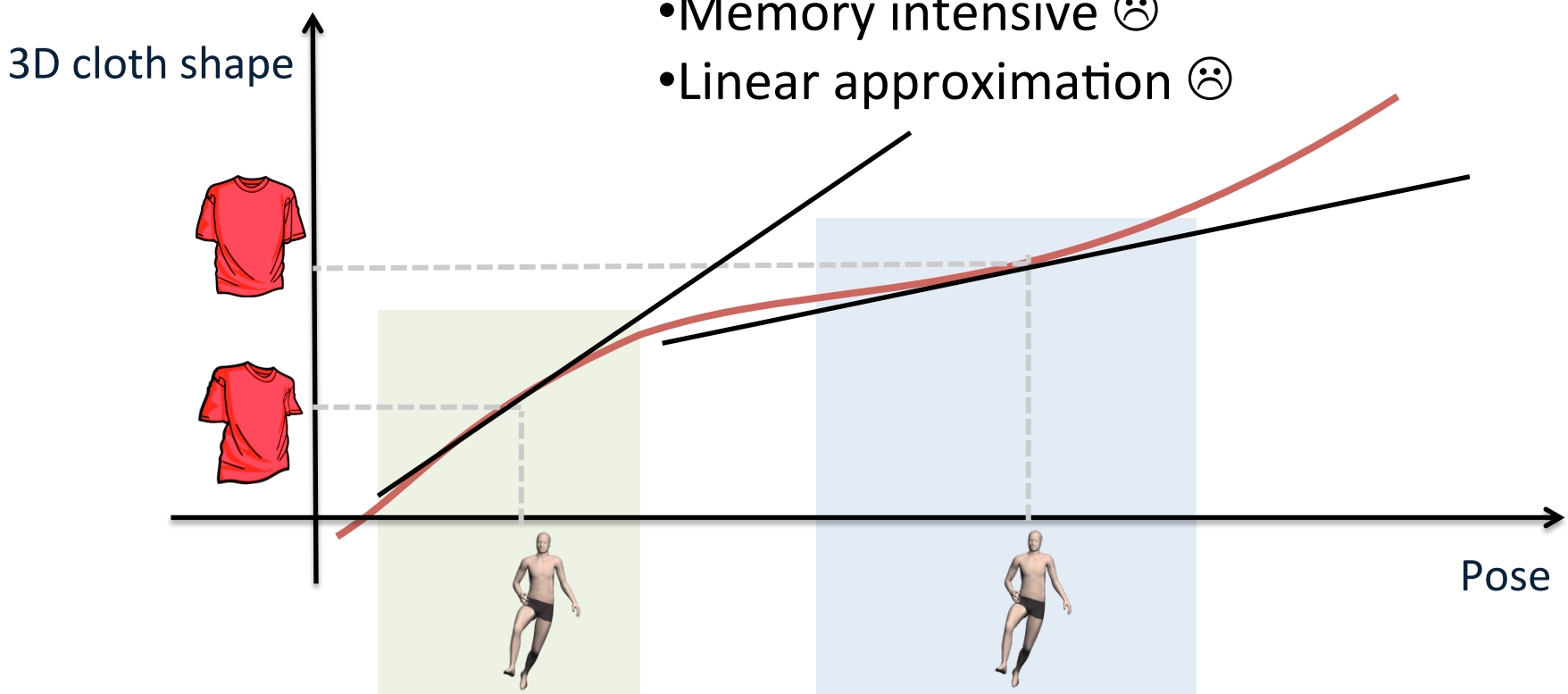


# 1st order Prediction of Clothing Deformation



# Sensitivity for Pose change

- Good representation around example ☺
- Memory intensive ☹
- Linear approximation ☹



# Skinning Weight Optimization

Linear Blend Skinning

$$y' = \sum_b \boxed{w_b} \left( \mathbf{R}_b y + \mathbf{T}_b \right)$$

optimize

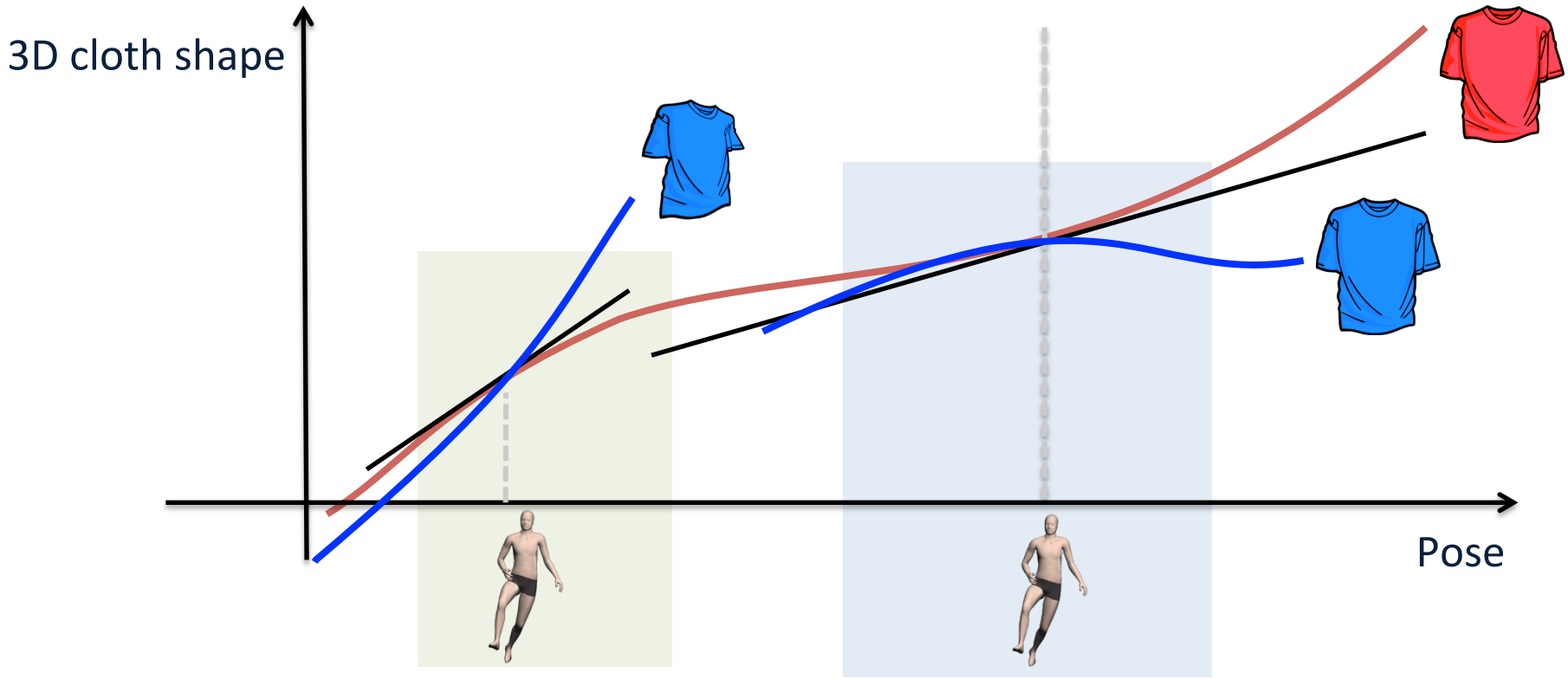
$$\underset{w_b}{\arg\min} \left| \frac{\partial}{\partial} \quad - \quad \frac{\partial}{\partial} \right|$$

rigged

simulated

# Sensitivity for Pose Change

- Optimize weight to best approximate sensitivity



# Optimized Clothing Rigging Weight

FPS:144.27

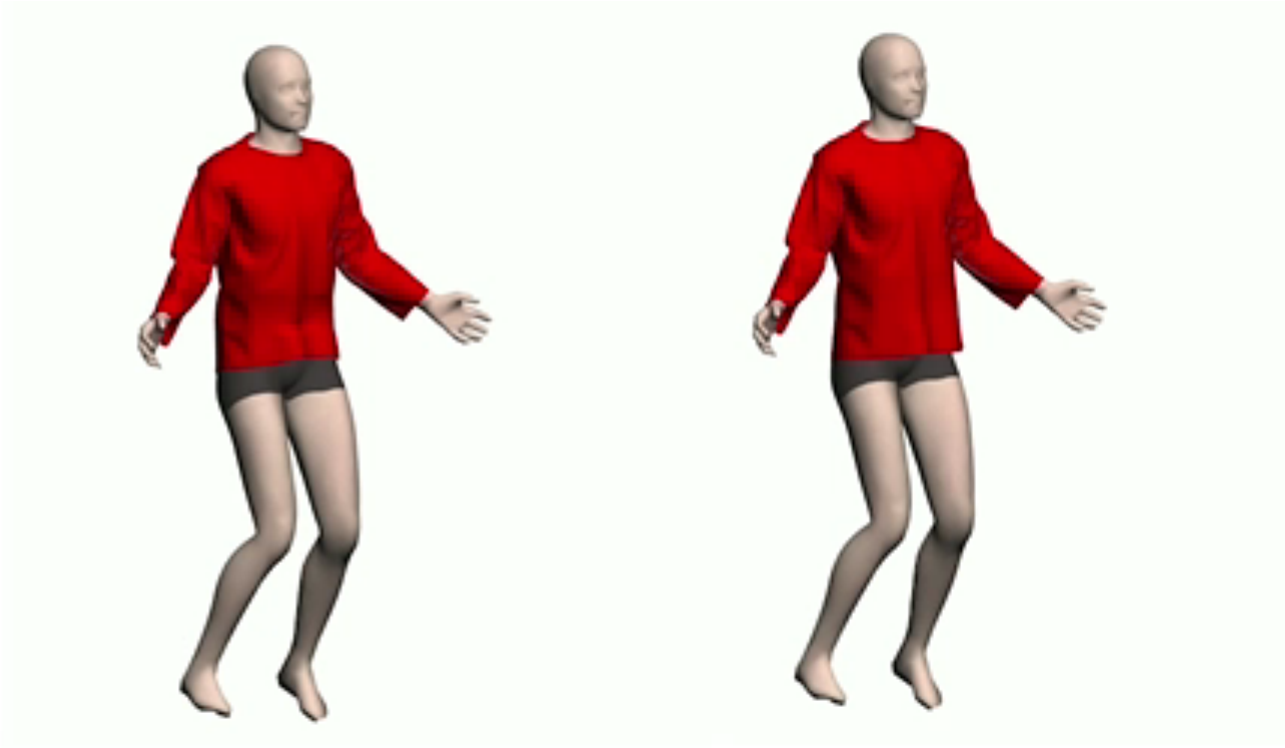
Body weight

Naïve clothing weight

Optimized clothing weight

# Comparison against Naïve Weight

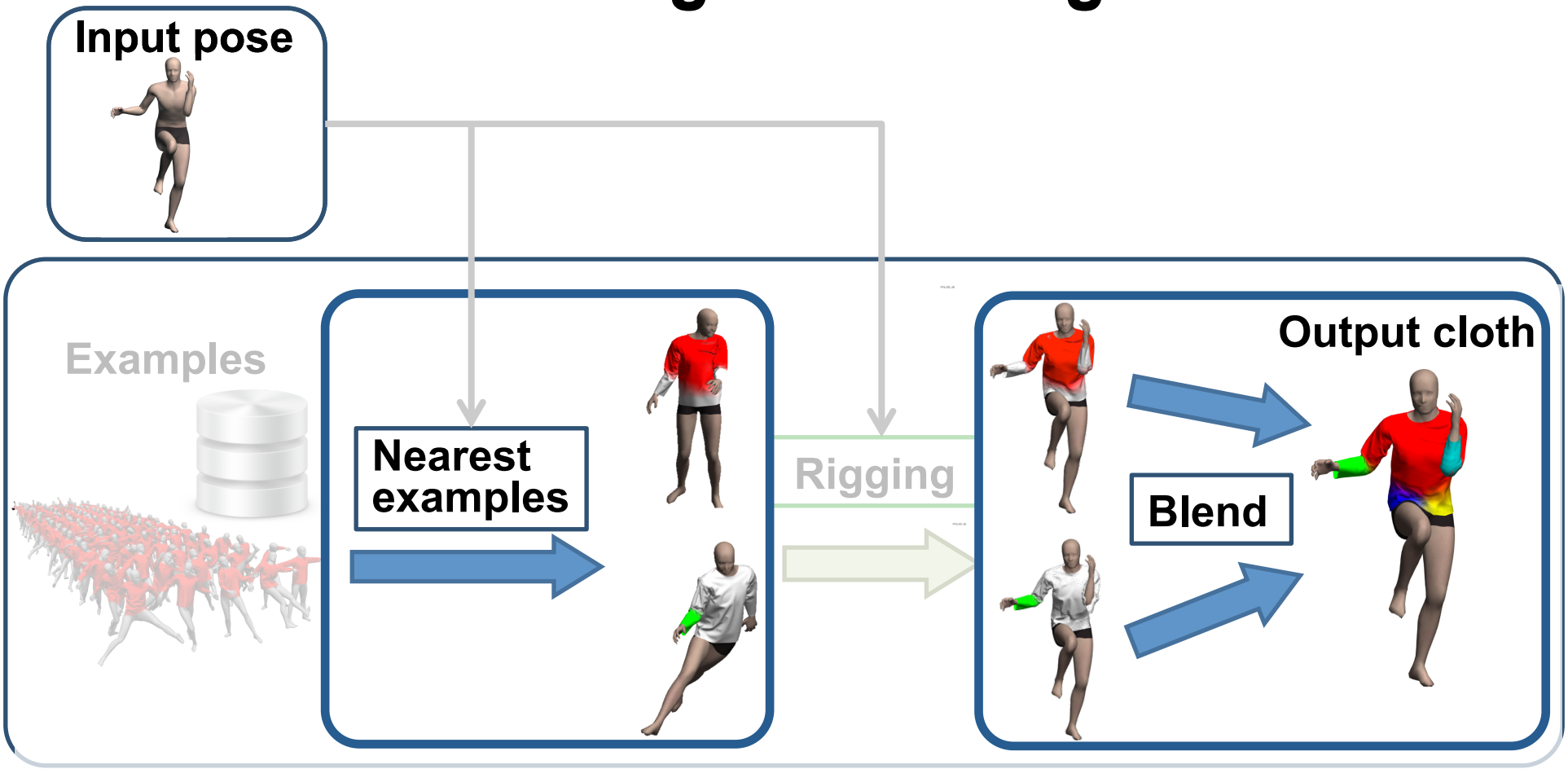
Example cloth



Naïve clothing weight

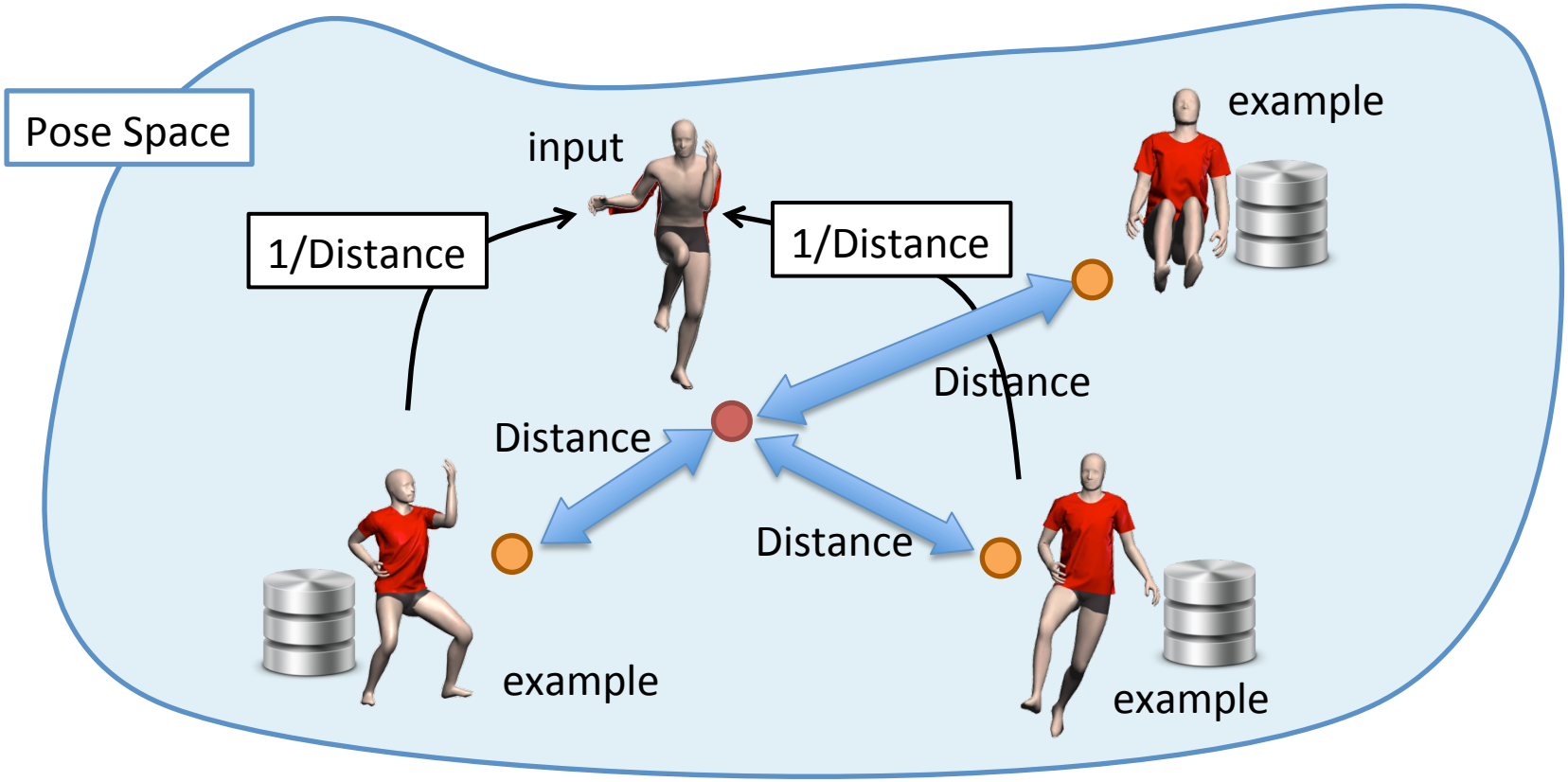
Optimized clothing weight

# Procedure: Skinning & Blending



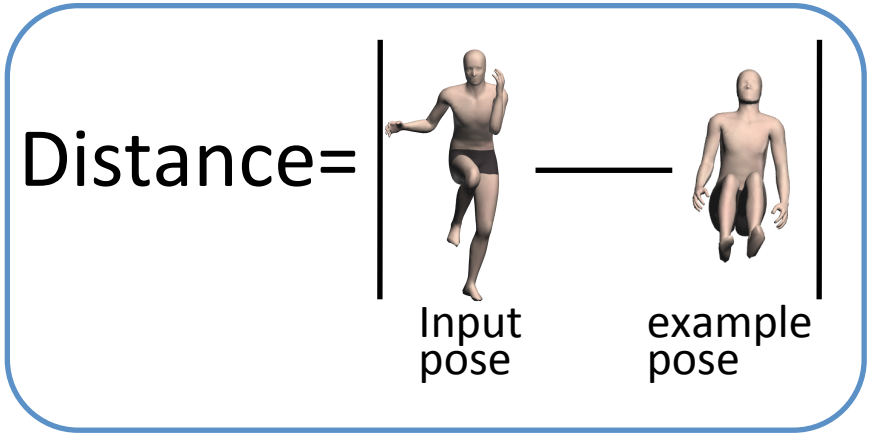
# Selecting & Blending with Distance Measure

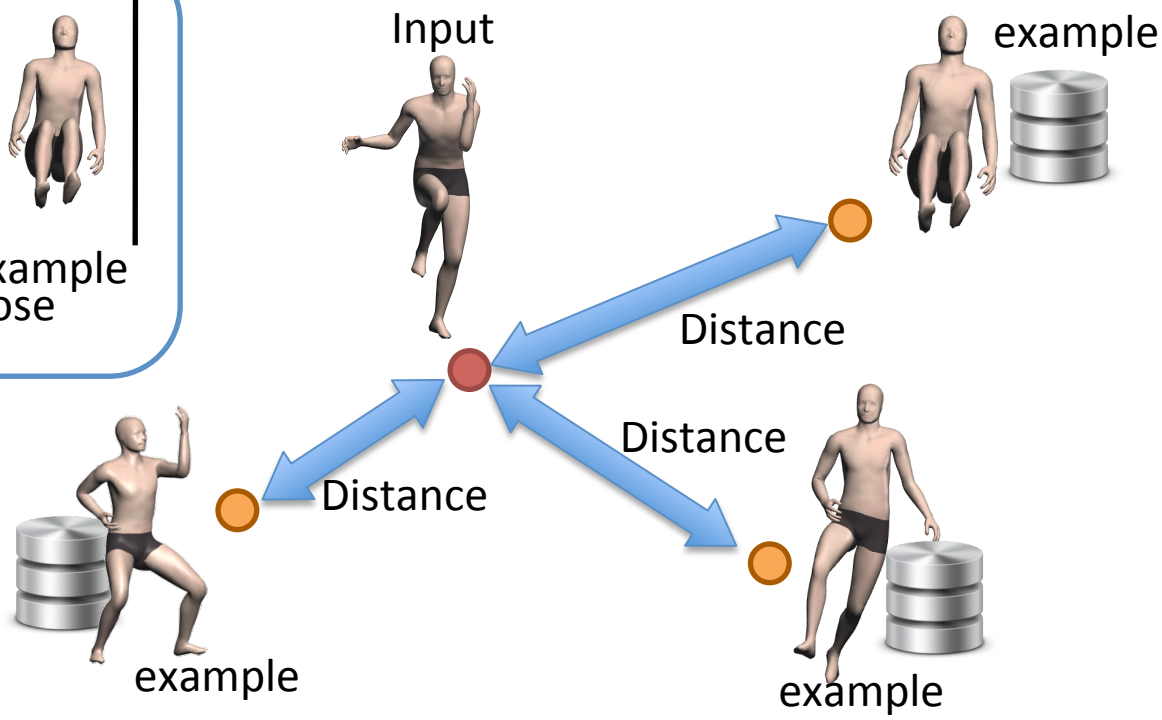
- K-Nearest neighbor interpolation



# Distance Measure

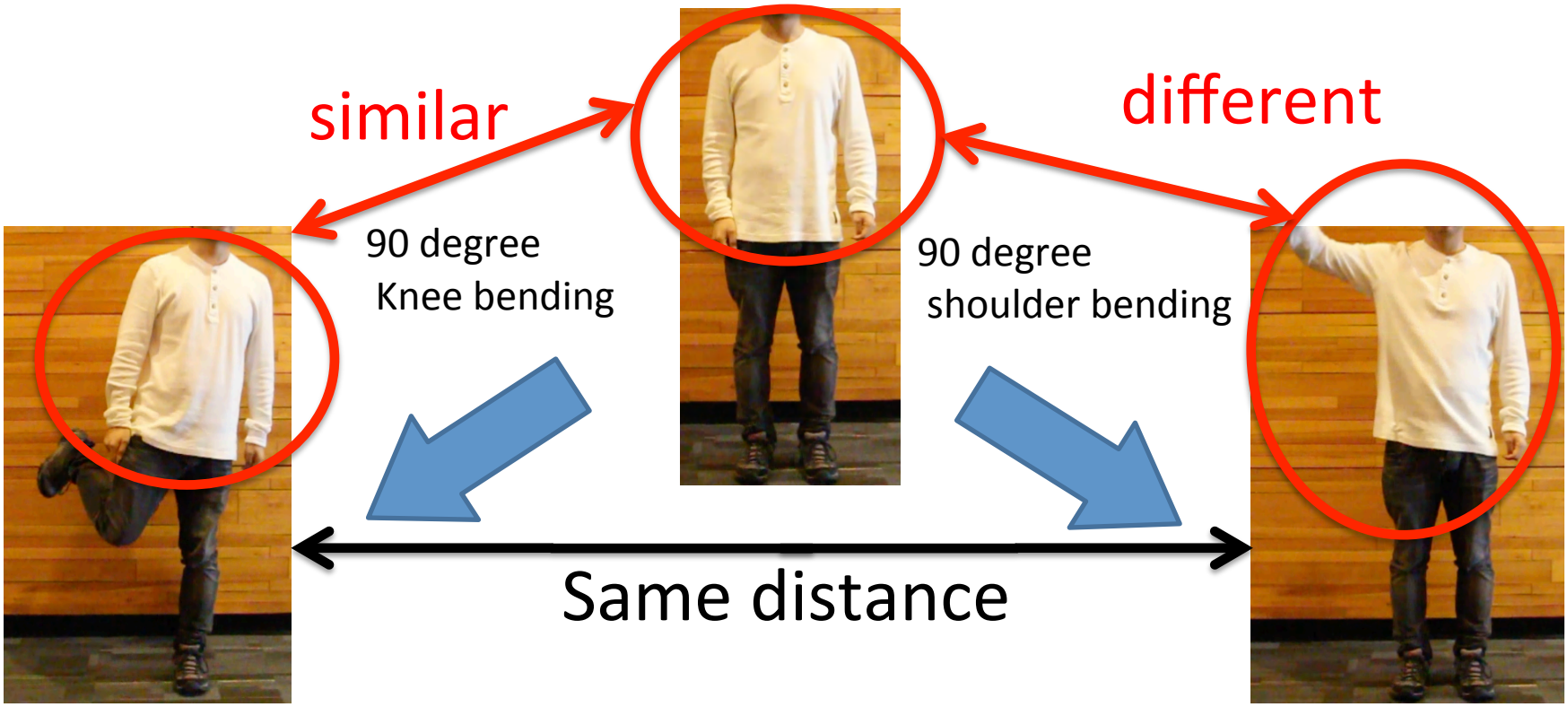
- Compare body shape or joint angles difference



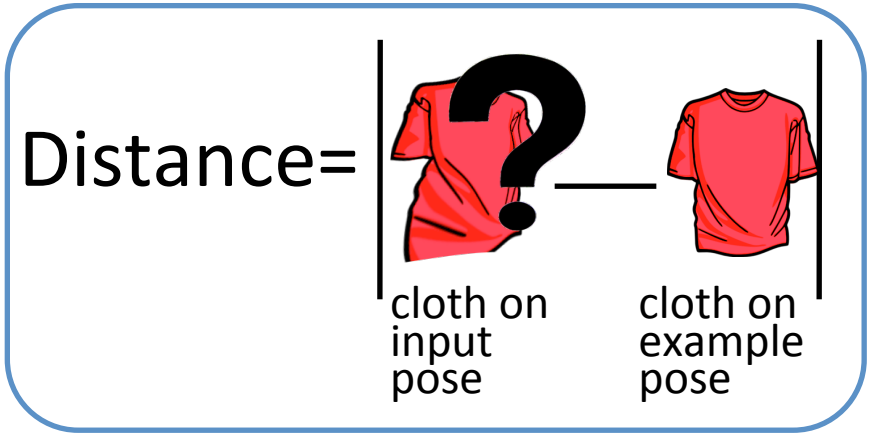
# Drawback of the Typical Approach

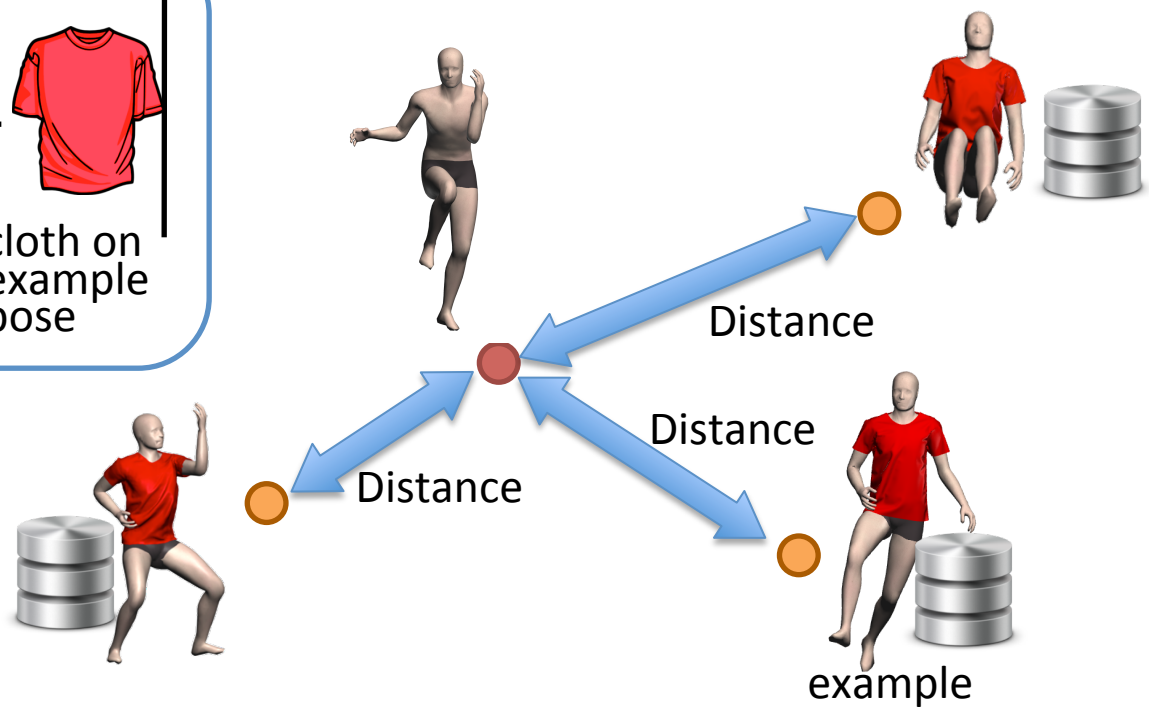
- Cannot tell amount of influence of joint to cloth



# Distance Measure: Our approach

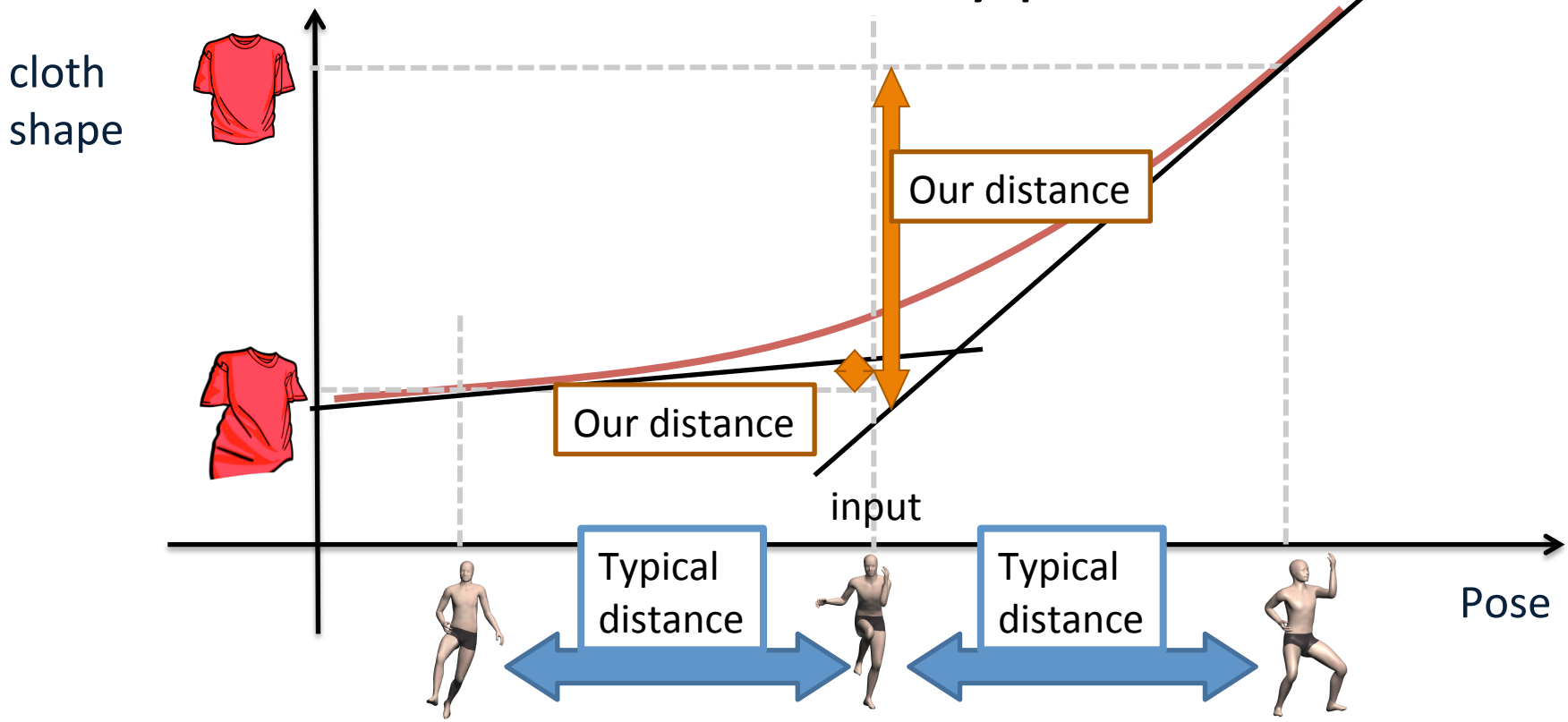
- Compare clothing shape difference



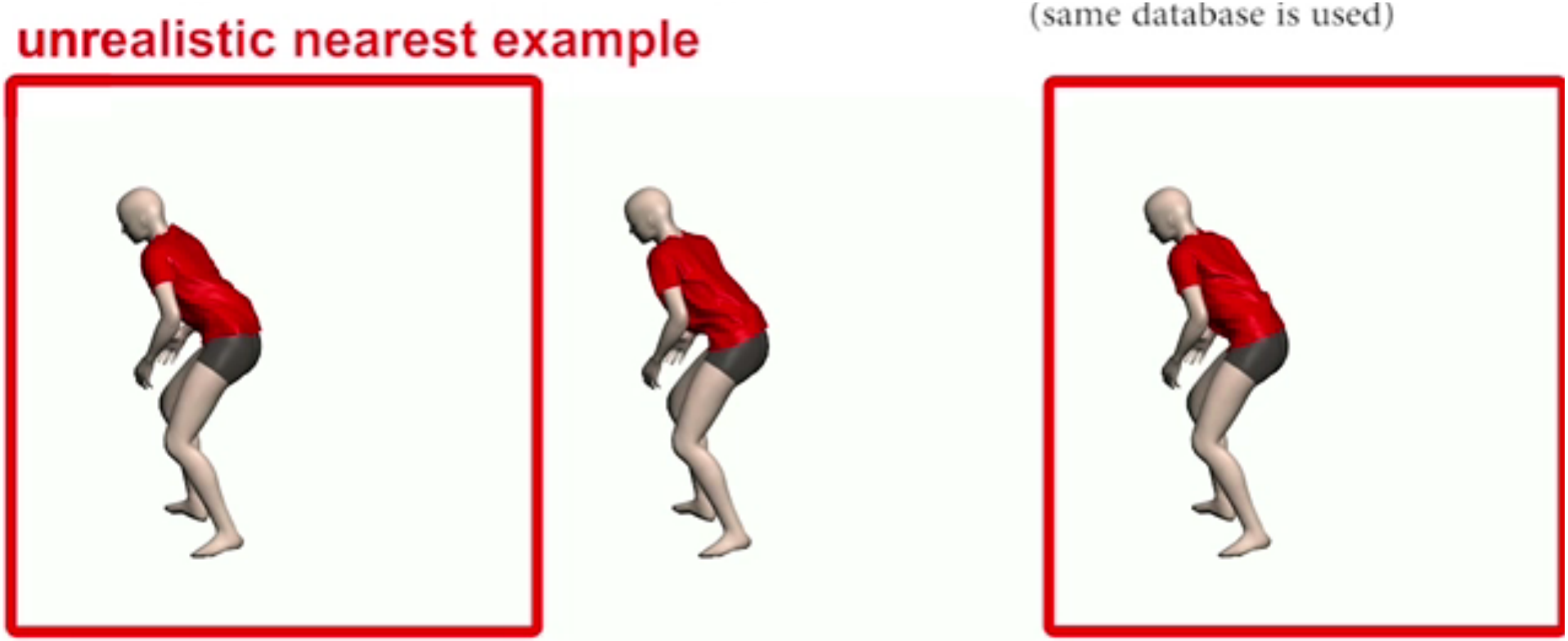
# Sensitivity-based Distance

- Difference between sensitivity predictions



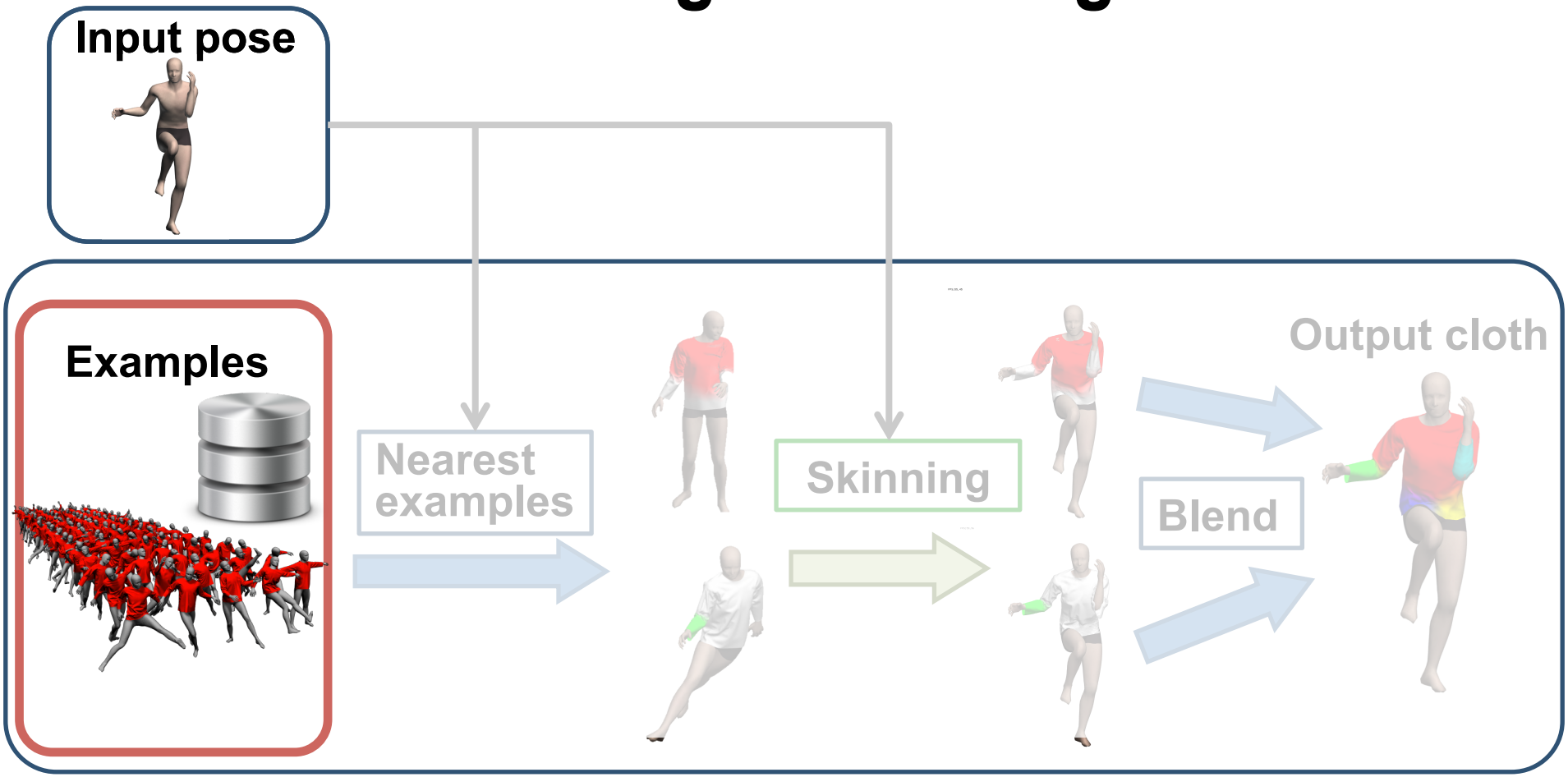
# Comparison with Naive Approaches

(same database is used)

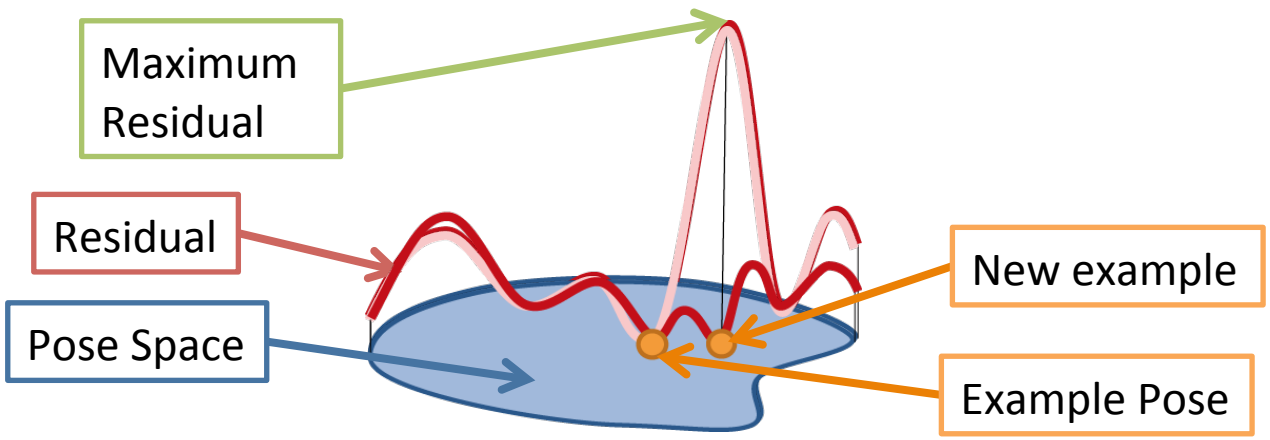


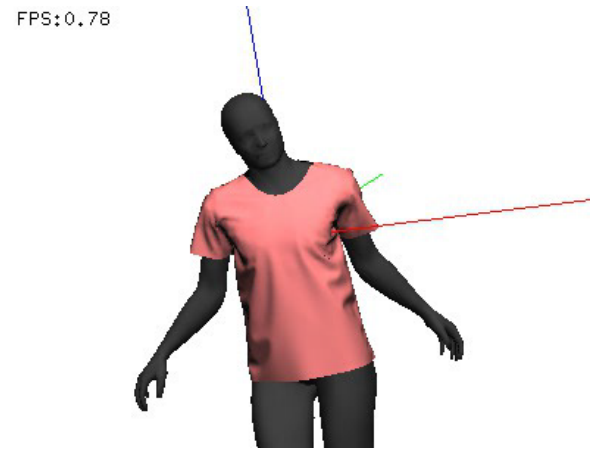

All joints angle | Nearest joint for each region | Our approach

# Procedure: Skinning & Blending



# Incremental Database Construction

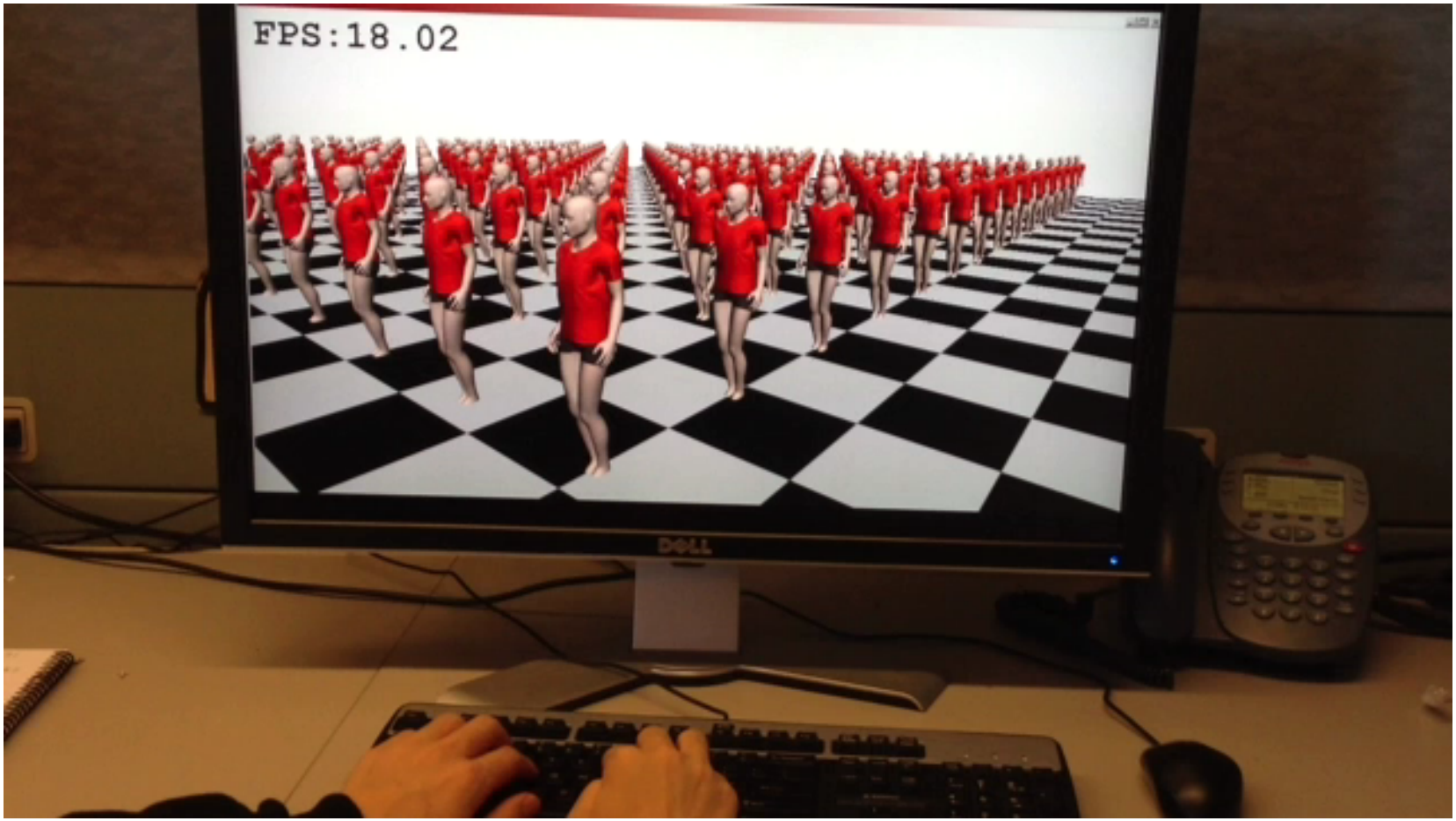


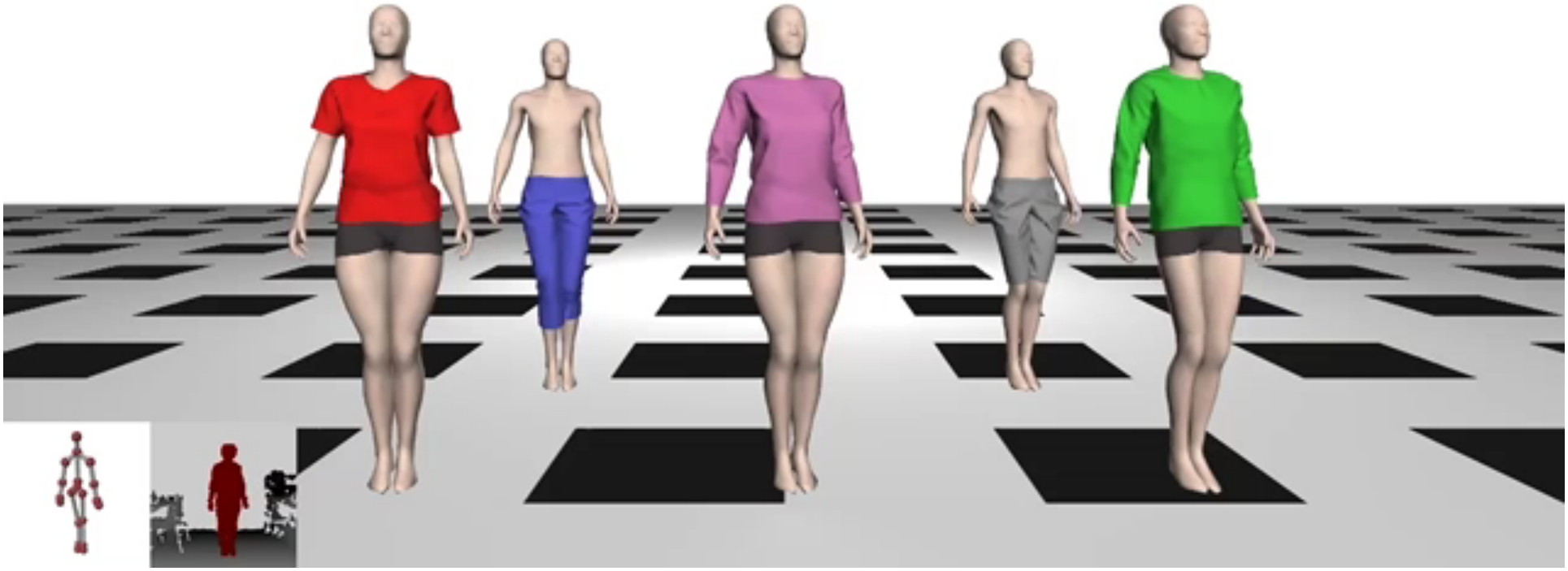

1. Find the maximum residual pose (MCMC method)
2. Solve cloth deformation at the pose
3. Add the deformation to database
4. Goto 1.

# More Results

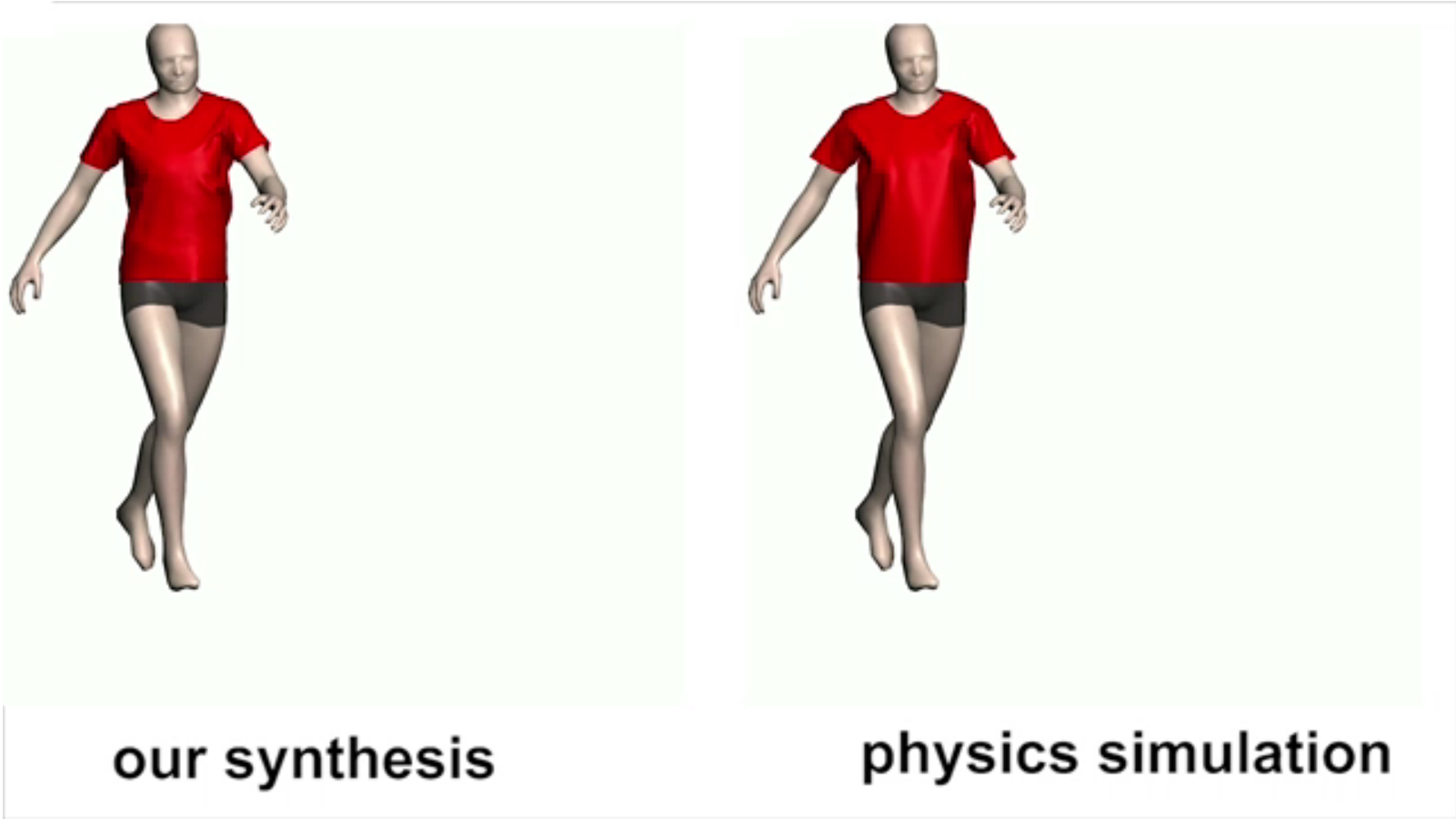
# Manipulating 200 characters using GPUs



# Kinect “try-on”



# Comparison with Physics Simulation



# Limitations

- Secondary motion
- Hysteresis
- Database accuracy guarantee

# Acknowledgement


- We would like to thank:
  - Anonymous Reviewer
  - CMU MoCap data
  - Ryan Schmidt and Michel Tao

- Funded by:
  - NSFC 61272392, 61322204, 61272298, 61328204
  - State Key Lab of CAD&CG, A1307
  - National High-tech R&D Program 2012AA011503

# Thanks for Your Attention!

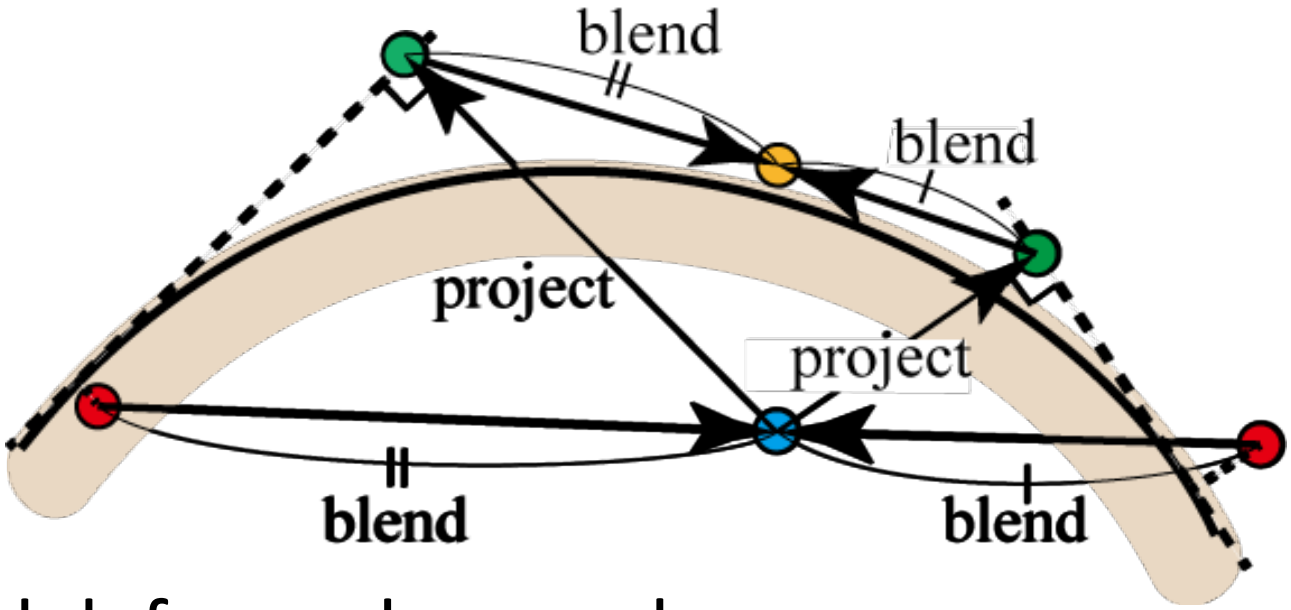
- Summary:

  Fast example-based clothing synthesis using rigging approach


# Database Size

| Clothing | T | LS | Sh | LP |
|---|---|---|---|---|
| $\lvert V_{\mathcal{Y}} \rvert$ | 11k | 12k | 10k | 12k |
| number of triangles | 22k | 22k | 19k | 22k |
| runtime frame rate (FPS) | 61 | 60 | 70 | 60 |
| $\lvert J \rvert$ | 150 | 120 | 100 | 170 |
| database size (MB) | 52 | 44 | 32 | 45 |
| construction time (hrs) | 32 | 26 | 21 | 42 |
| simulation 1 step (msec) | 1140 | 1220 | 920 | 1280 |

# Fast Cloth-Body Intersection Resolving




1. Blend deformed example
2. Project blended deformation for each example
3. Blend the deformation again

# Result of Intersection Resolution

***Without*** Resolution

***With*** Resolution