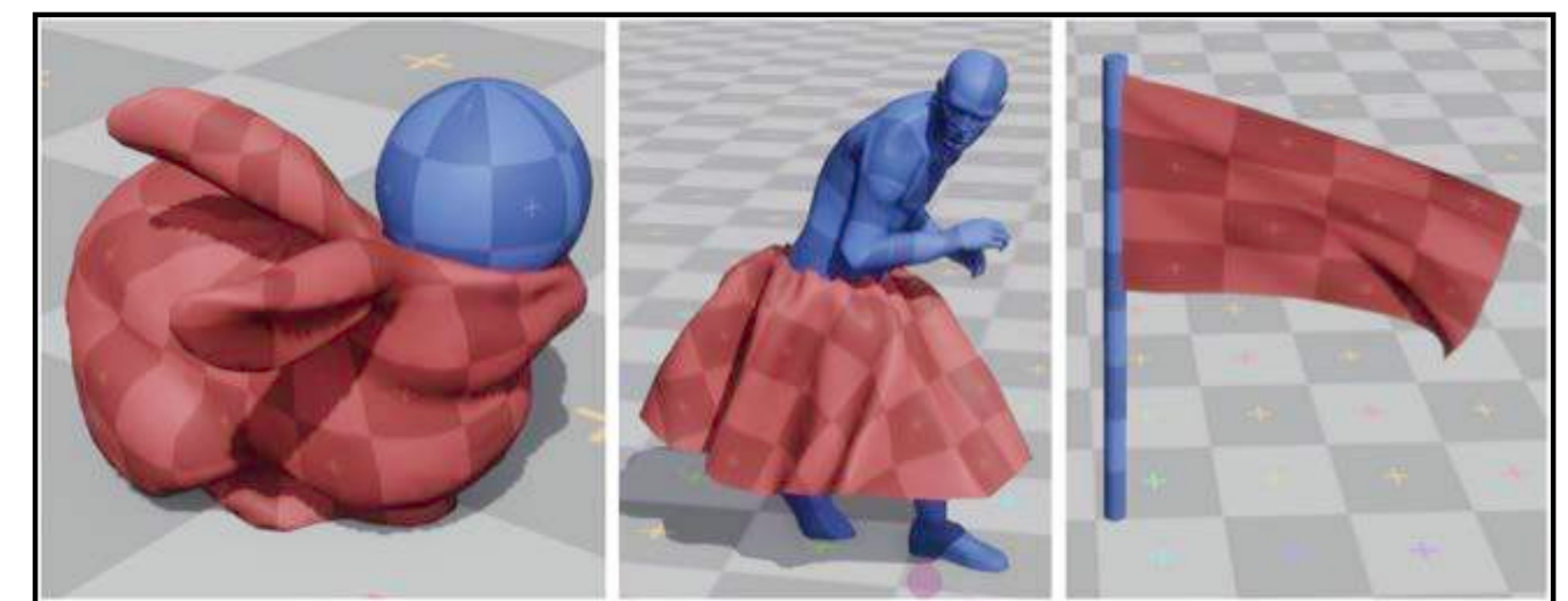
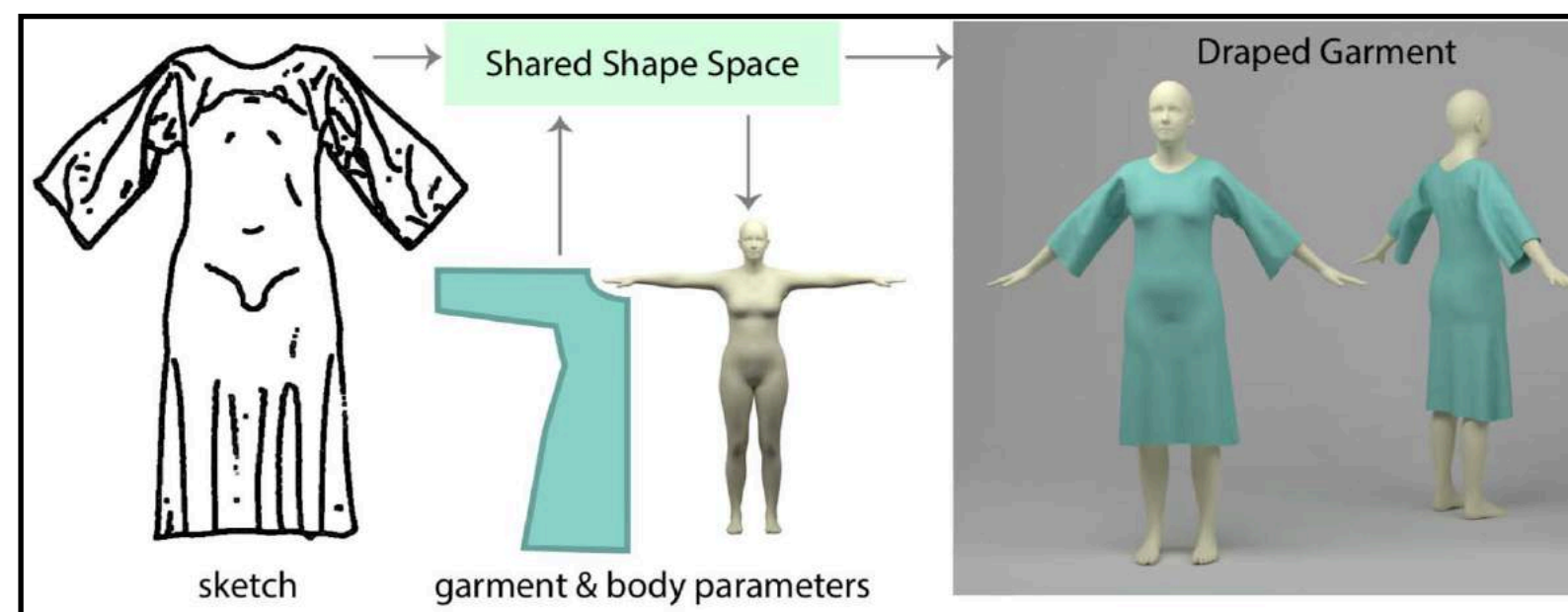
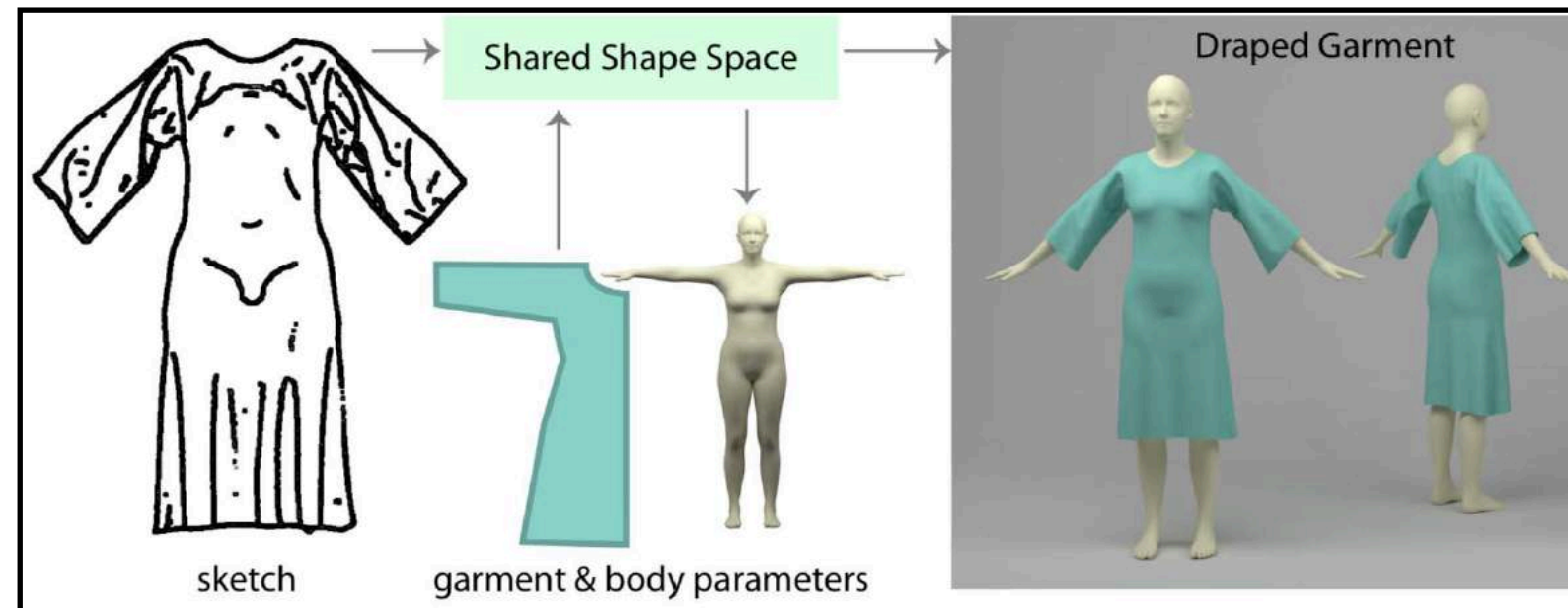


Learning for Garment Modeling and Animation Authoring

王杨转风 Tuanfeng Y. Wang

米哈游 逆熵科技 *miHoYo Inc.*

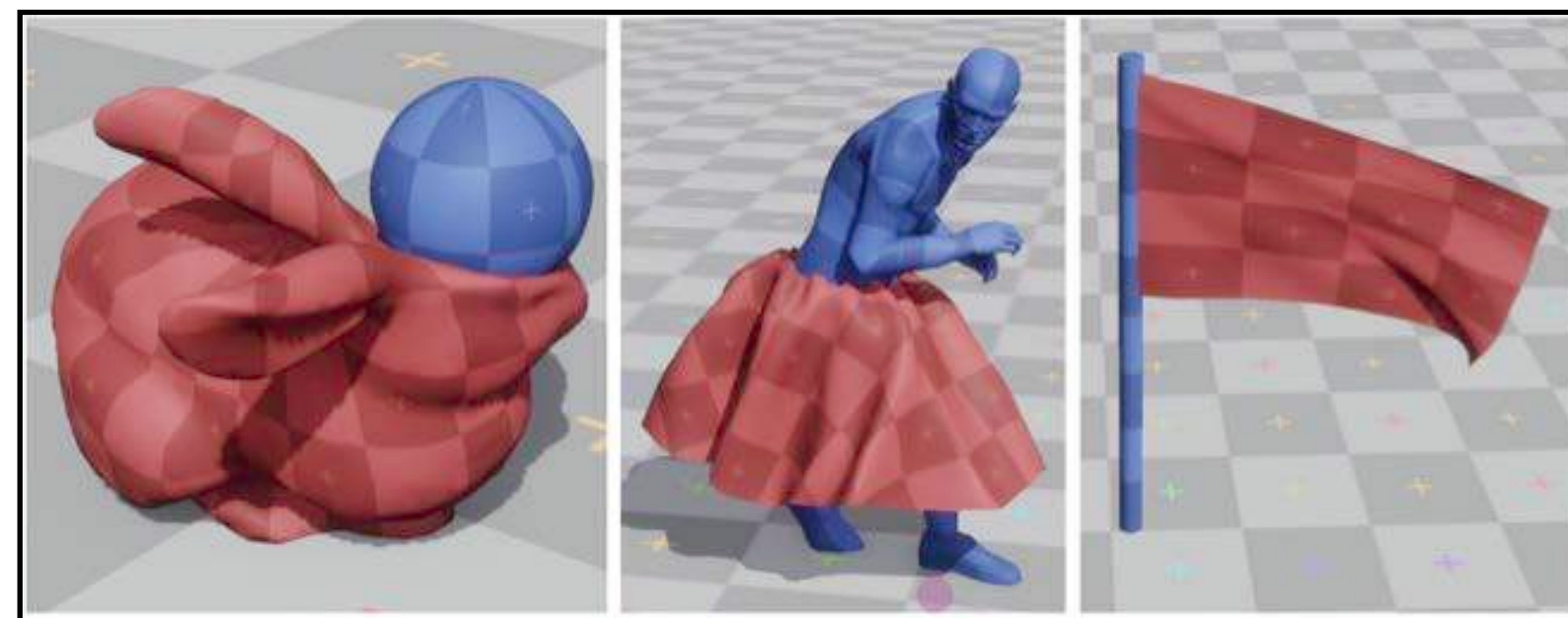




How to bridge 2D artistic fashion design, cloth sewing pattern, and 3D garment shape in a data driven framework. [Wang et al. 2018]



How to animate a statistic garment shape driven by character body motion and allow interactive user editing to the animation. [Wang et al. 2019]



How to formulate garment motion in an industry perspective. [Holden et al. 2019]



**Algeria
13000 BC**



**Old Kingdom
Egypt, 2600 BC**



**Western Han
China, 206 BC**



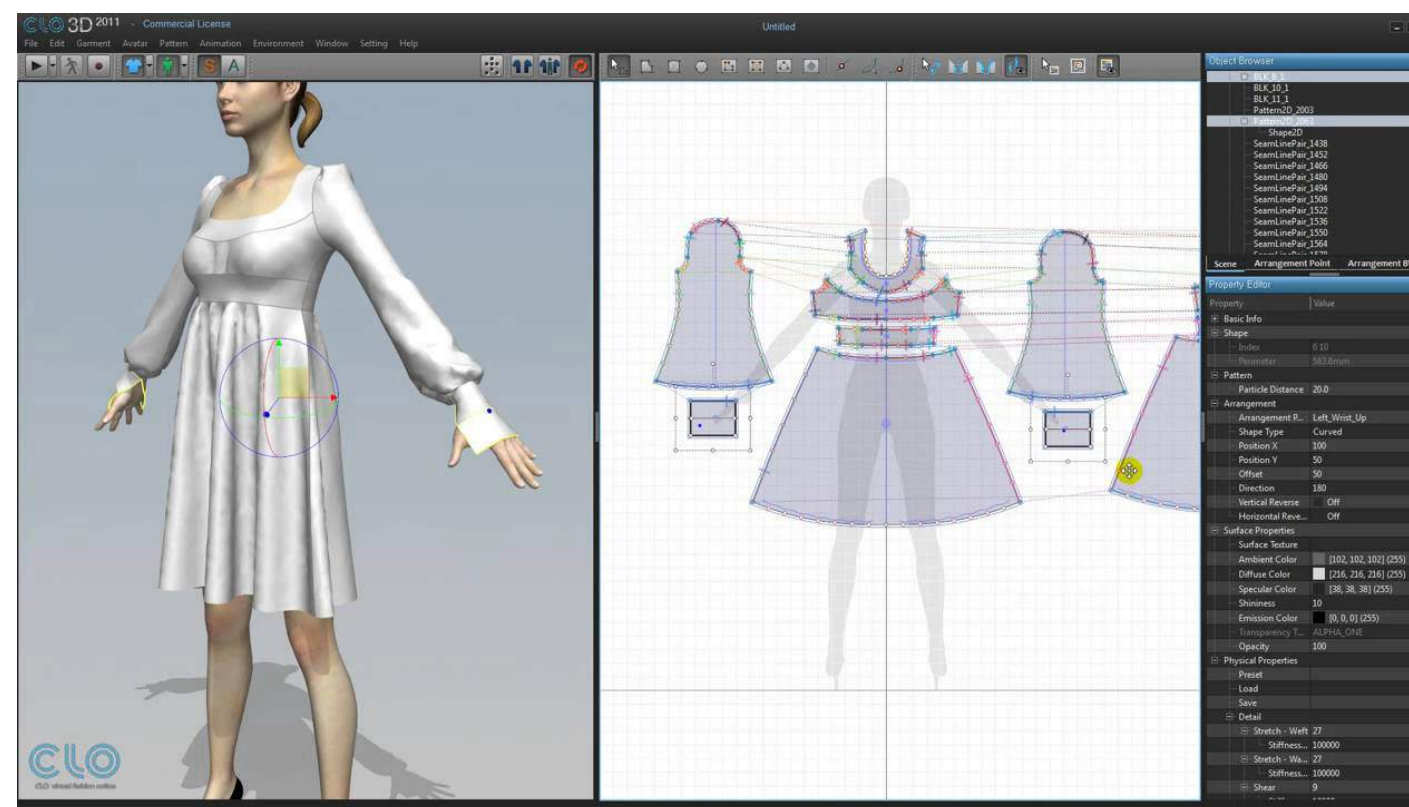
**Chanel
1924 AD**



**Versace
1994 AD**

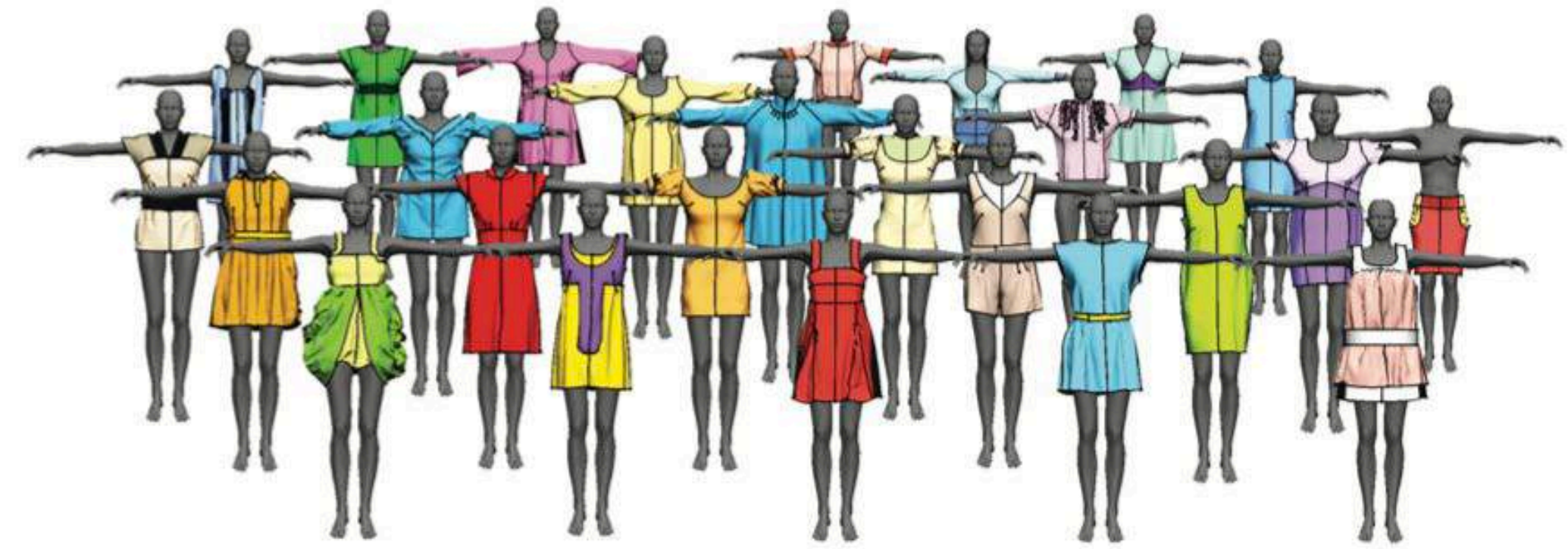


**Burberry
2016 AD**





Narain et. al. 2012



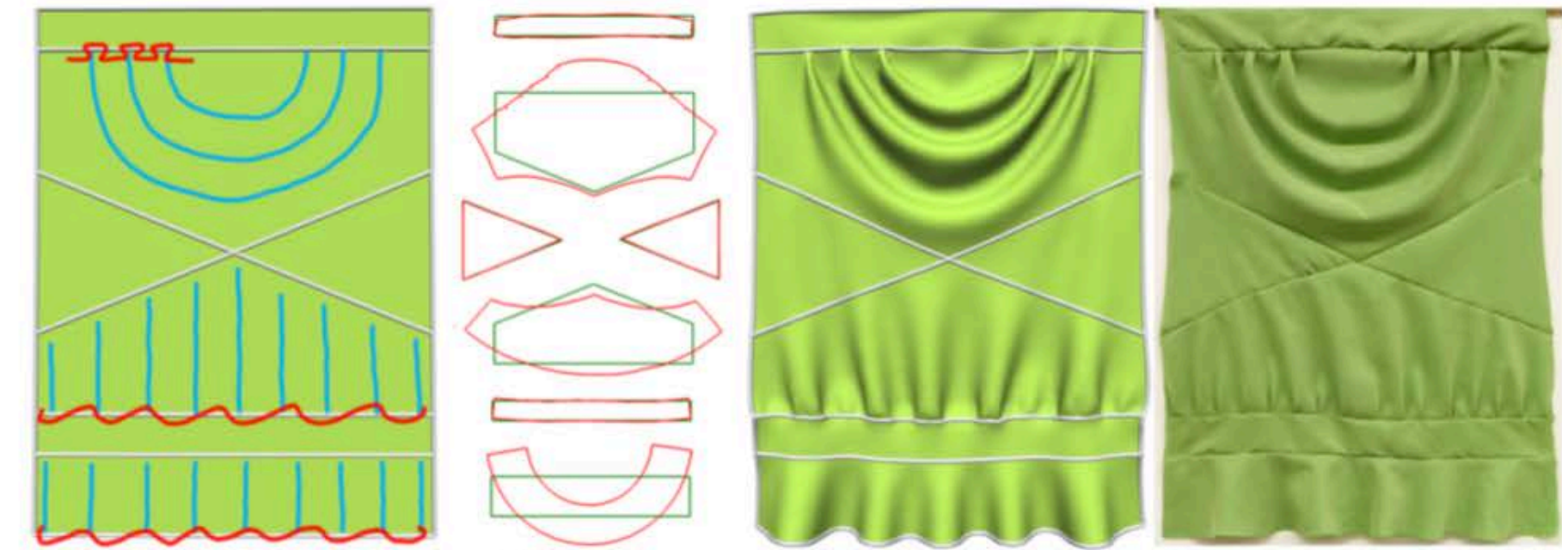
Berthouzoz et. al. 2013



Pons-moll et. al. 2017



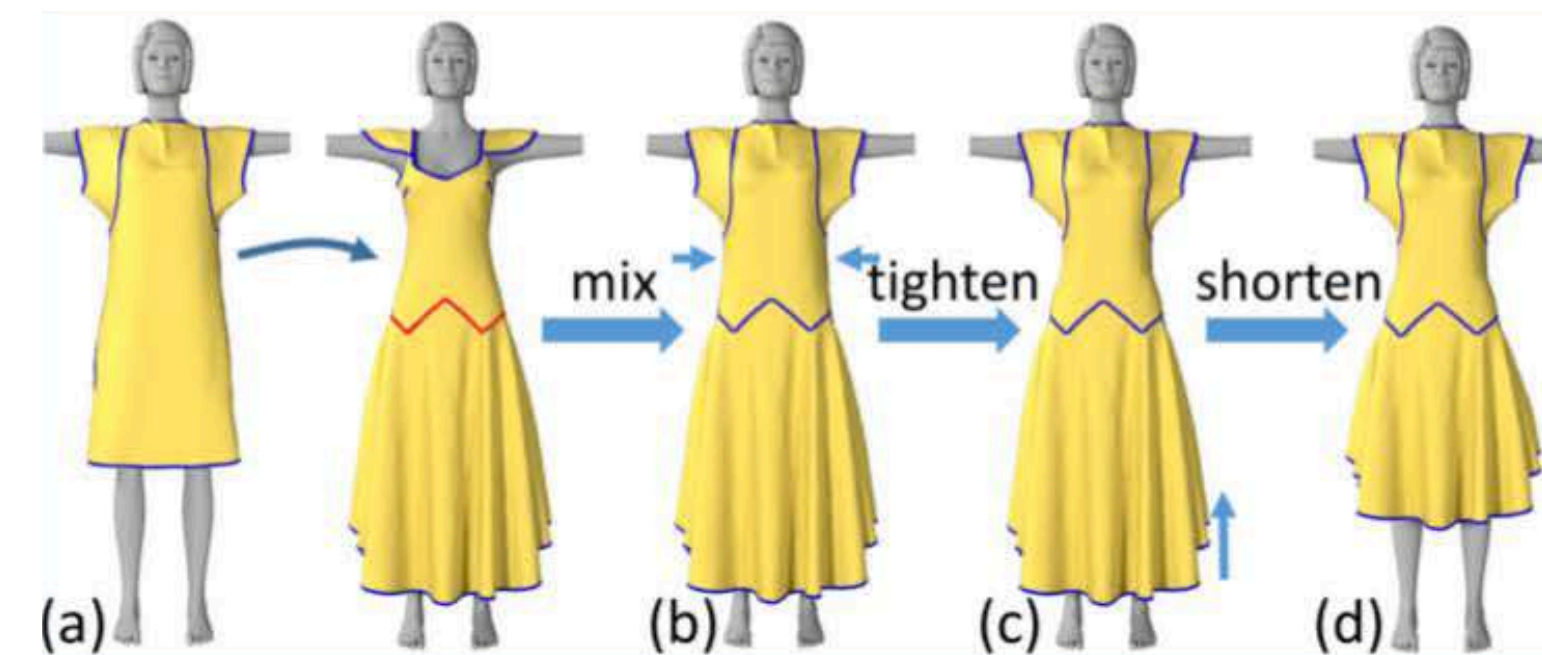
Yang et. al. 2016



Li et. al. 2018



Jung et. al.



Bartle et. al. 2017



Narain et. al. 2012



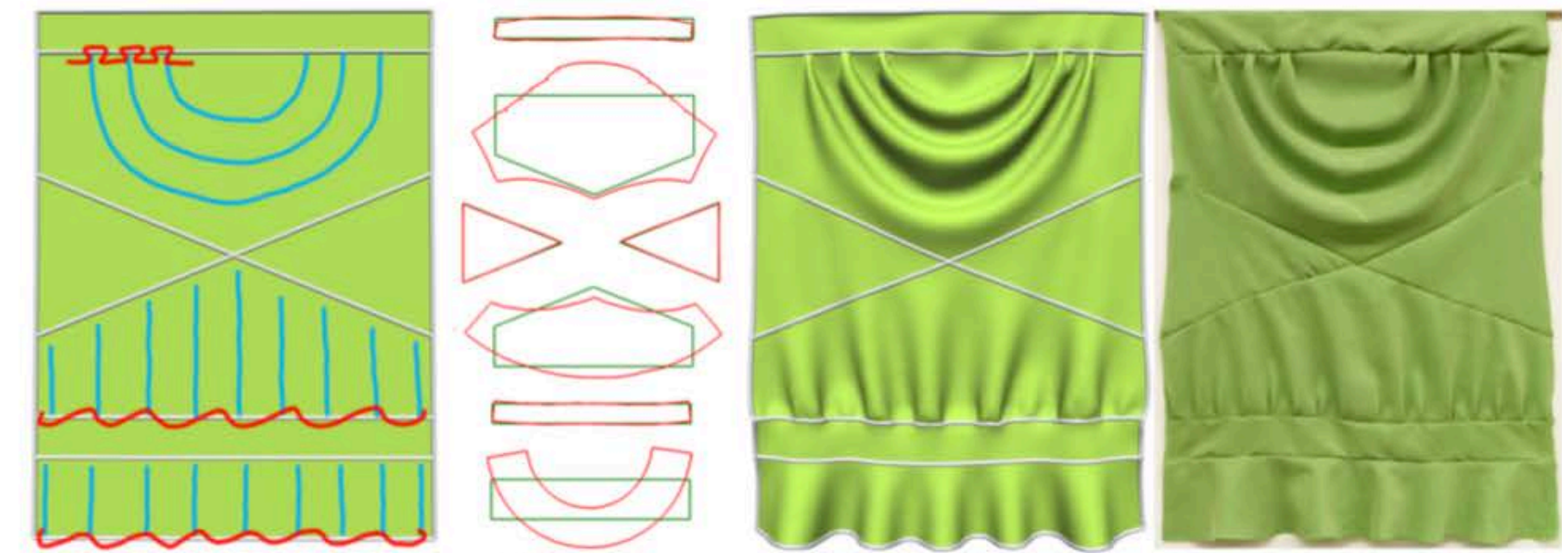
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Pons-moll et. al. 2017



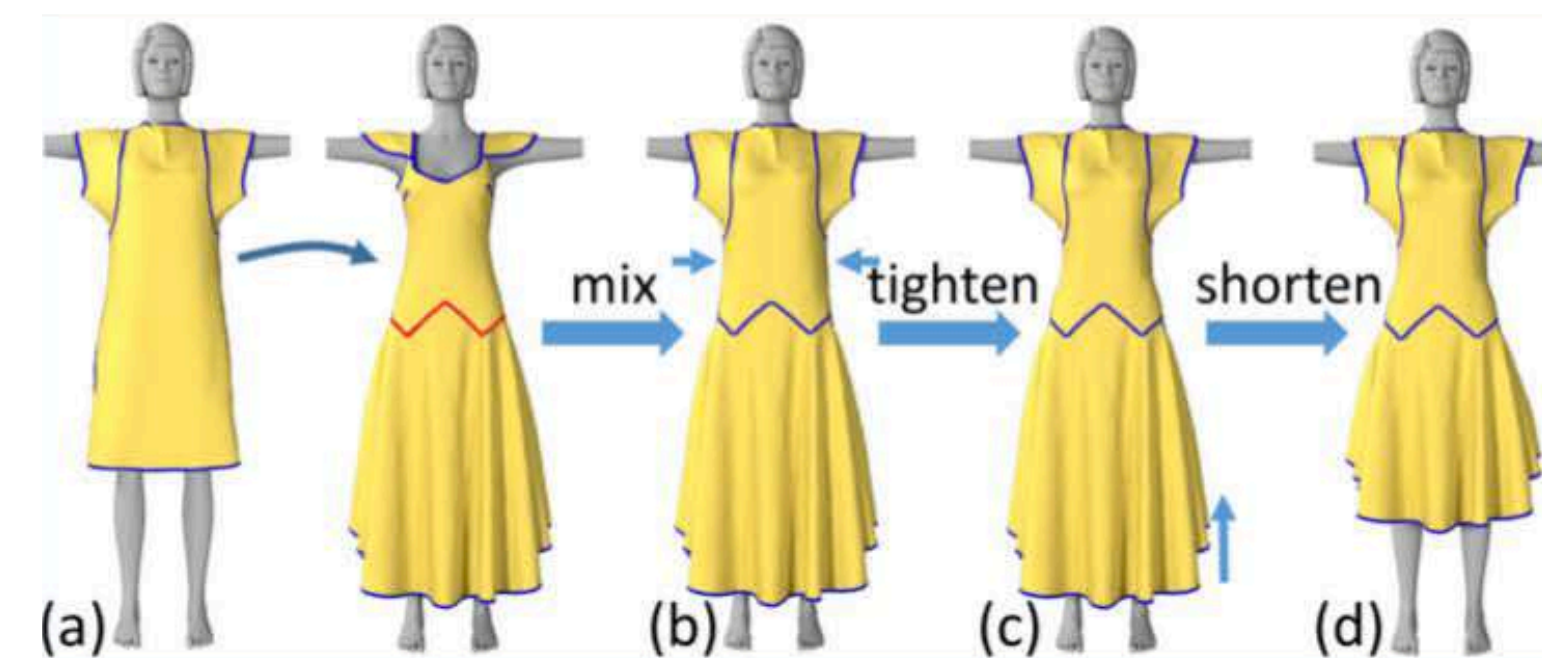
Yang et. al. 2016



Li et. al. 2018



Jung et. al.



Bartle et. al. 2017



Narain et. al. 2012



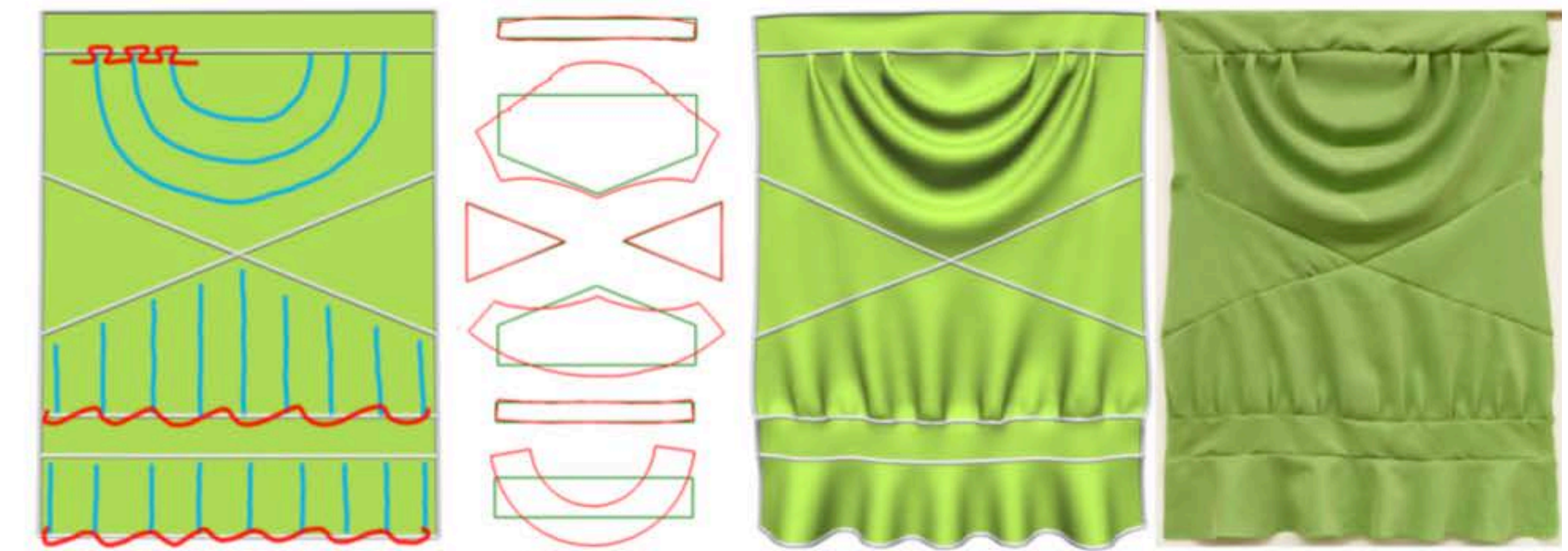
Berthouzoz et. al. 2013



Pons-moll et. al. 2017



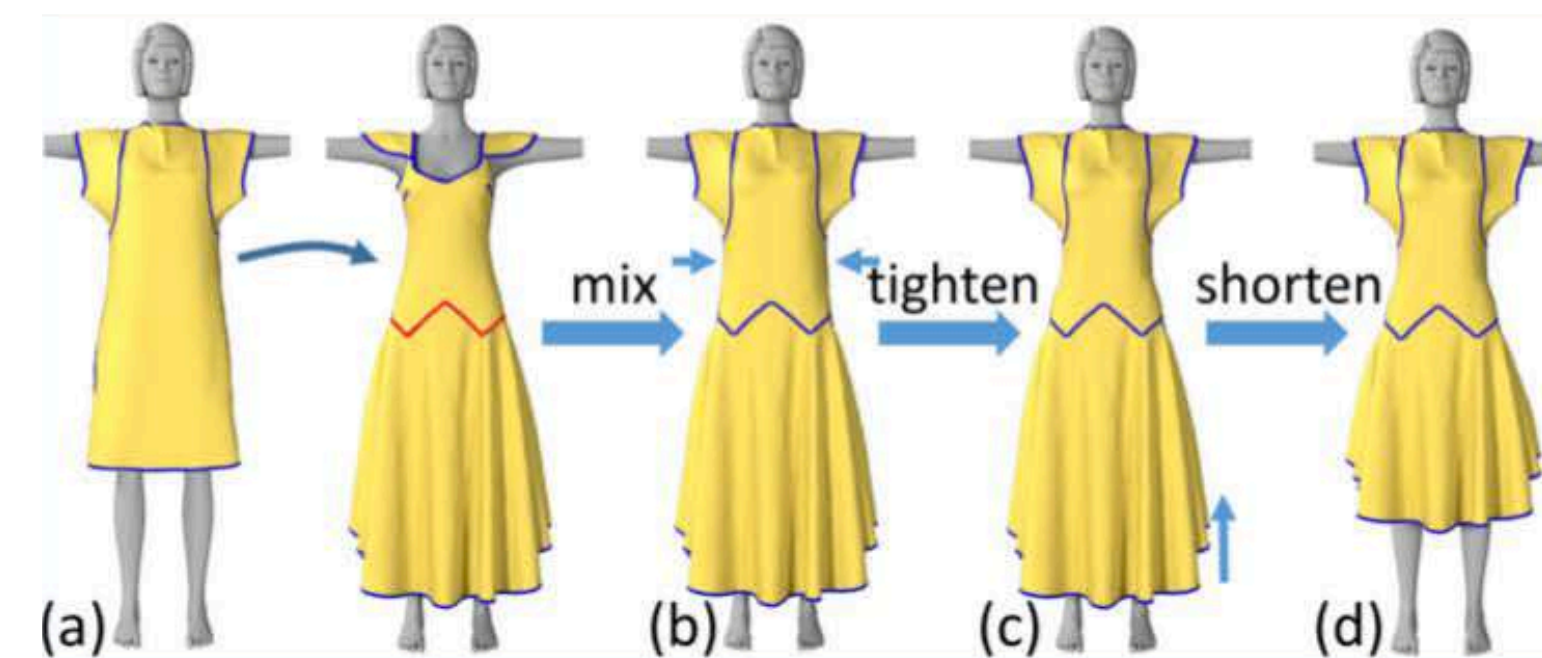
Yang et. al. 2016



Li et. al. 2018



Jung et. al.



Bartle et. al. 2017



Narain et. al. 2012



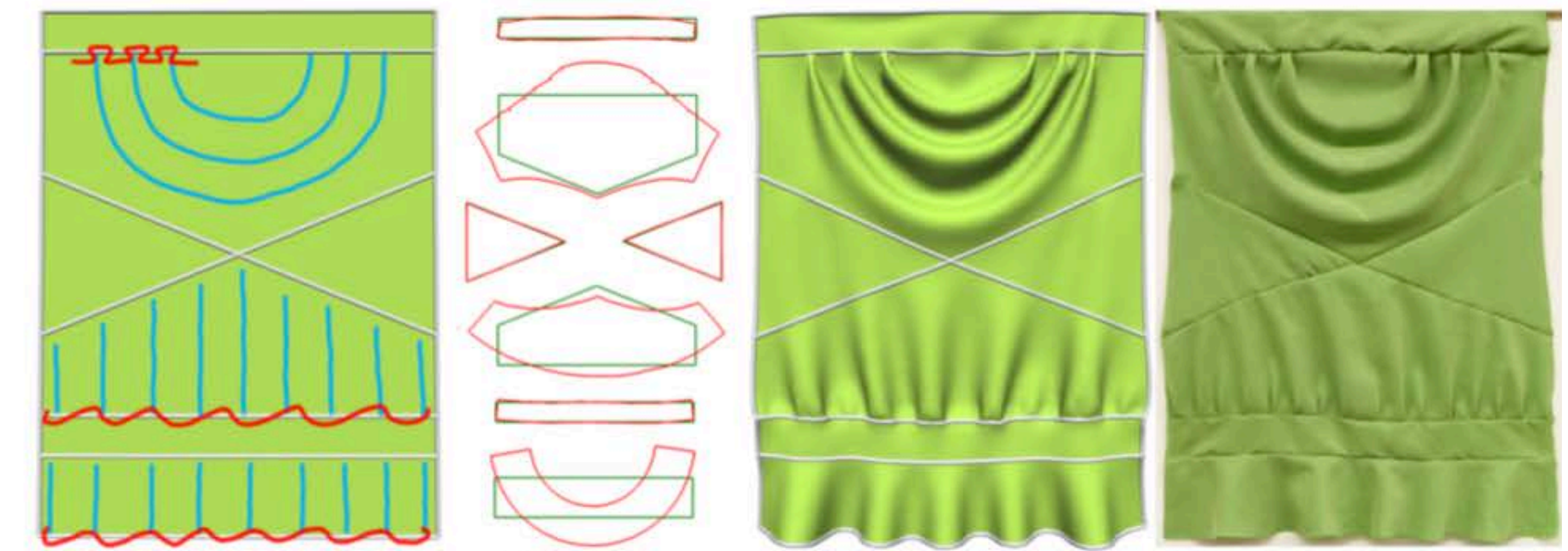
Berthouzoz et. al. 2013



Pons-moll et. al. 2017



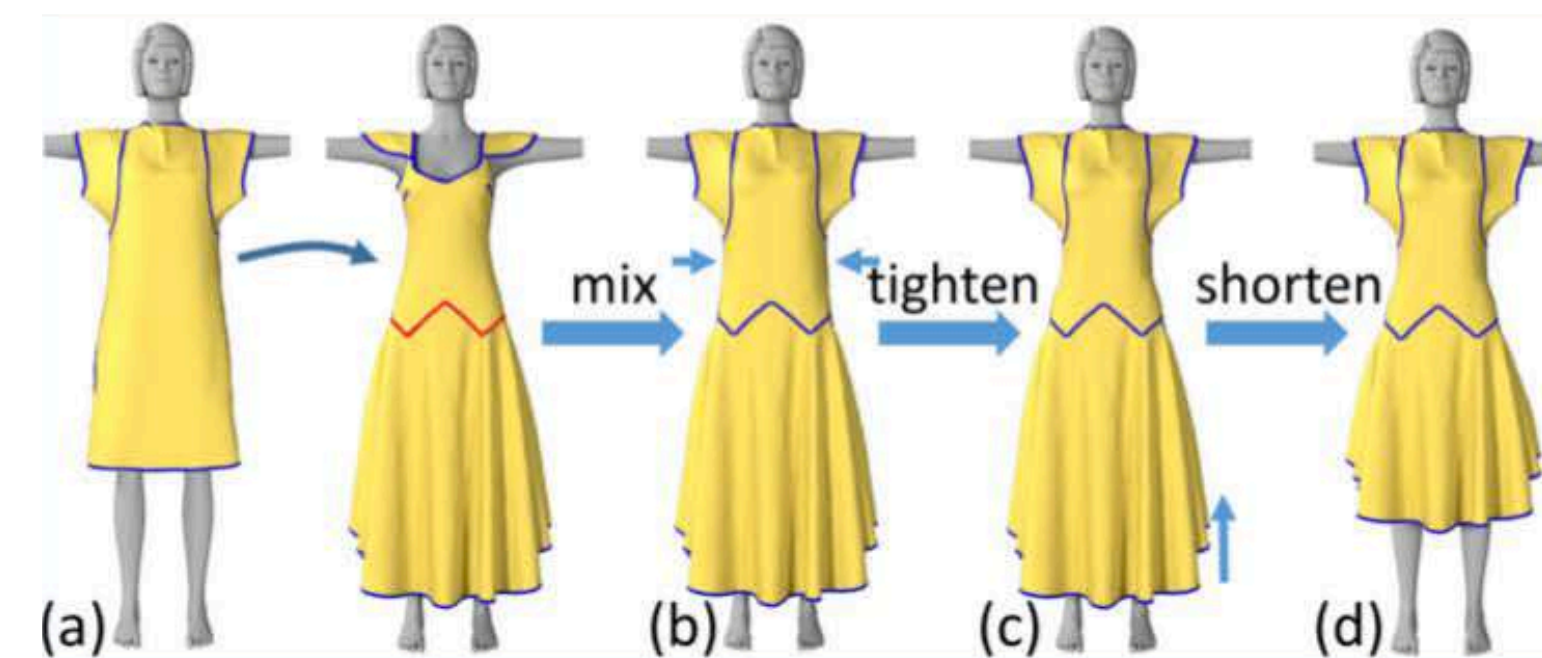
Yang et. al. 2016



Li et. al. 2018



Jung et. al.



Bartle et. al. 2017



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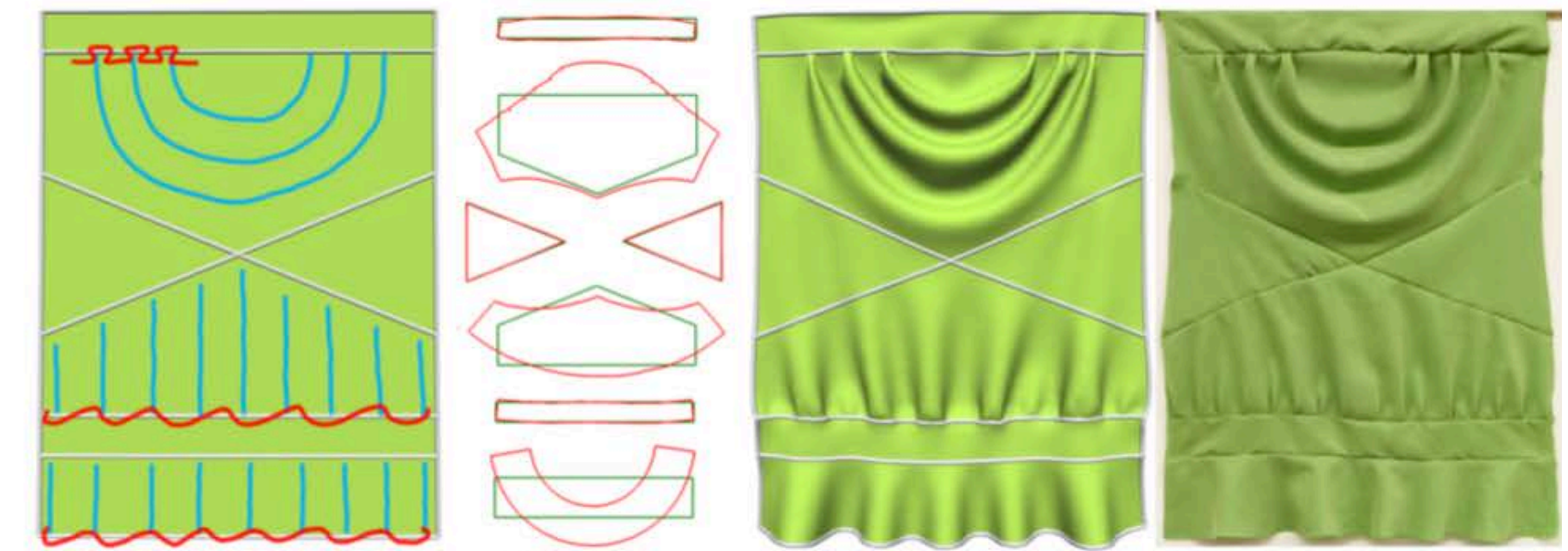
Berthouzoz et. al. 2013



Pons-moll et. al. 2017



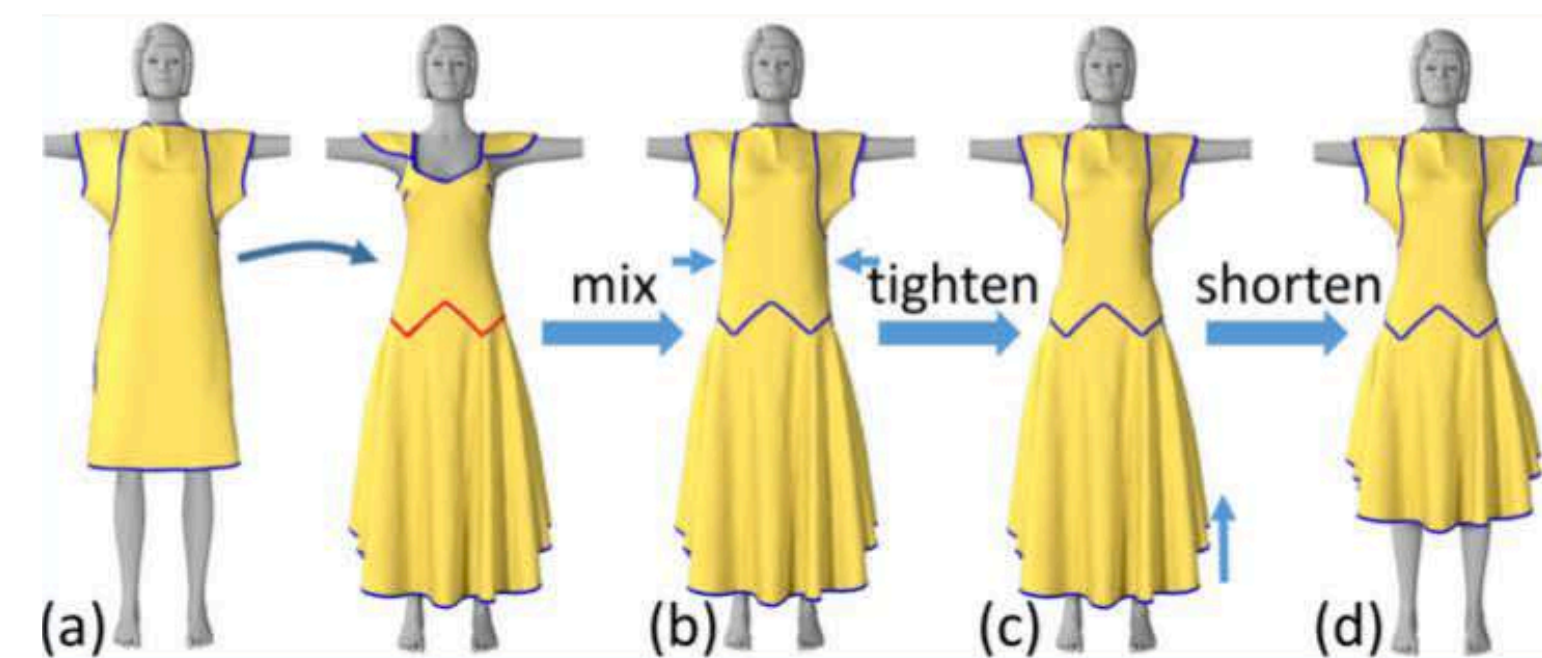
Yang et. al. 2016



Li et. al. 2018



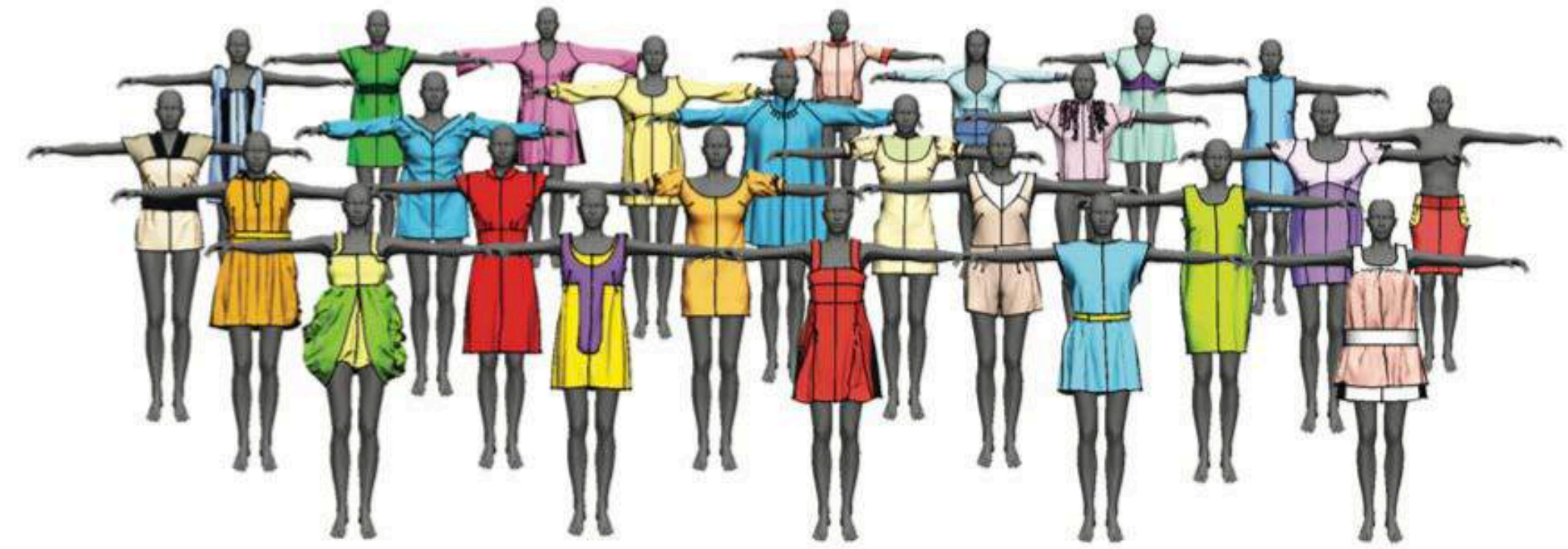
Jung et. al.



Bartle et. al. 2017



Narain et. al. 2012



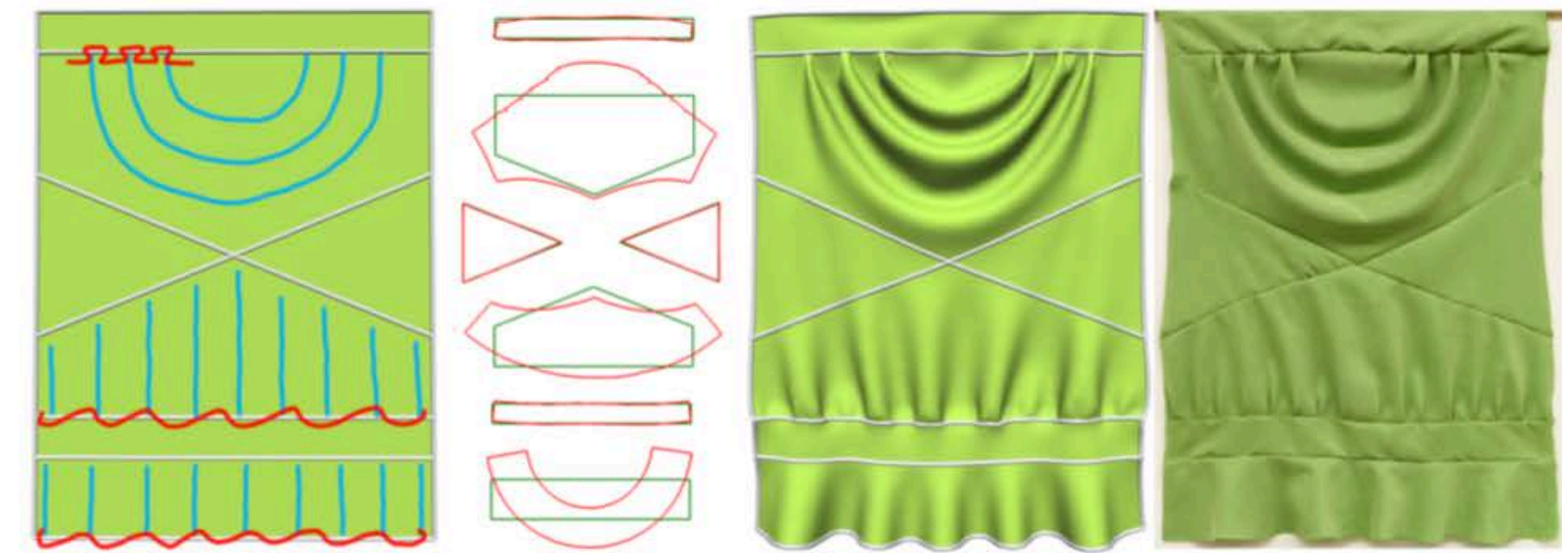
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Pons-moll et. al. 2017



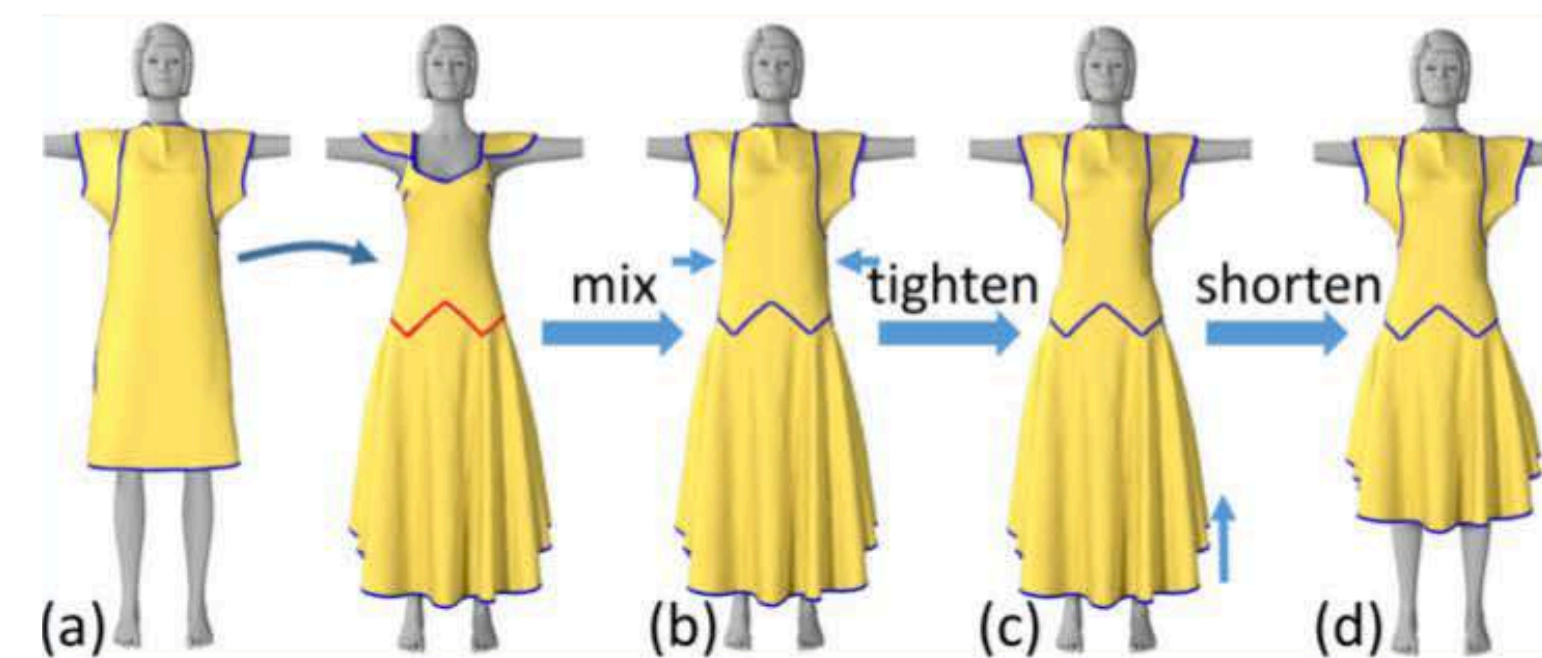
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Li et. al. 2018

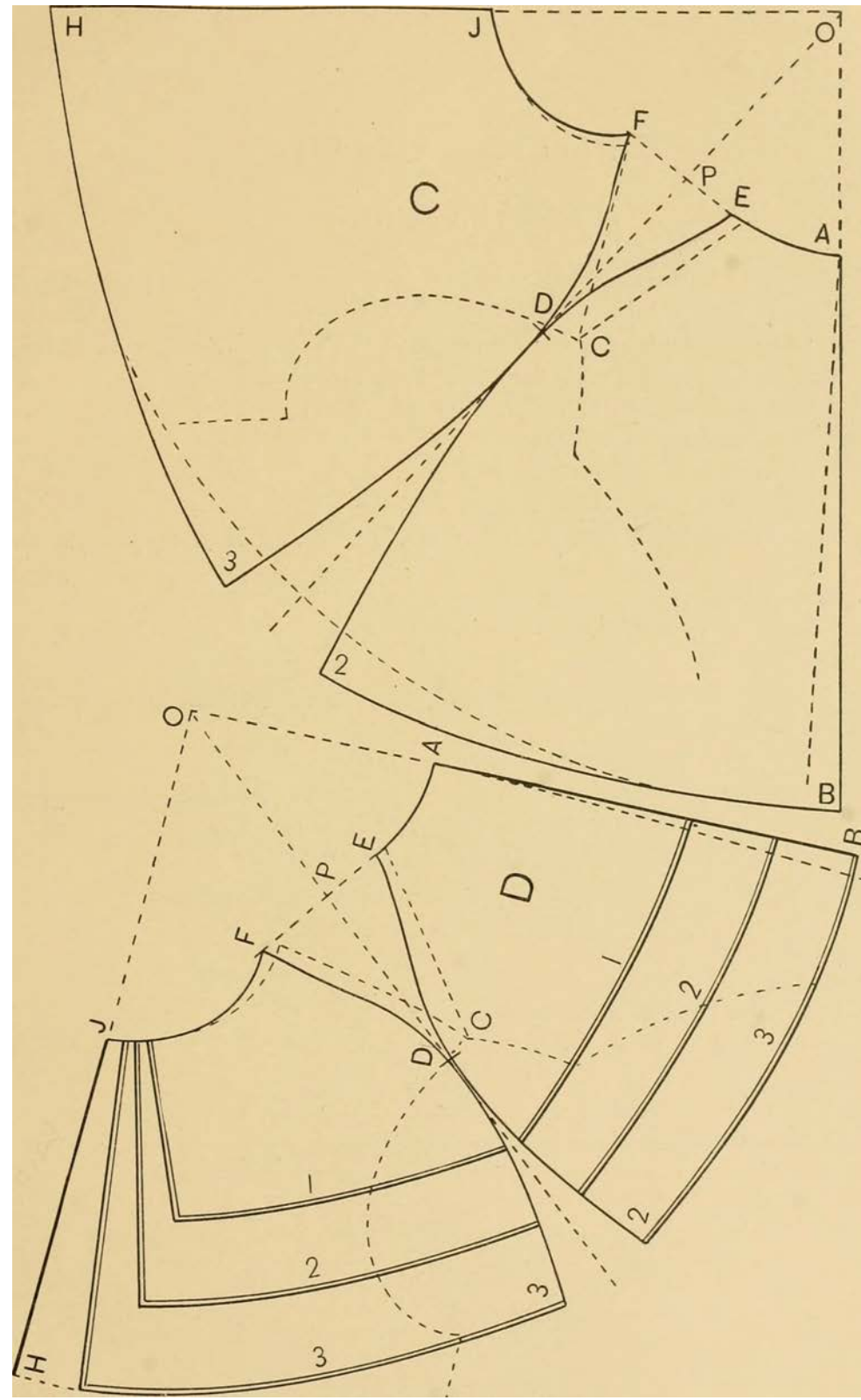
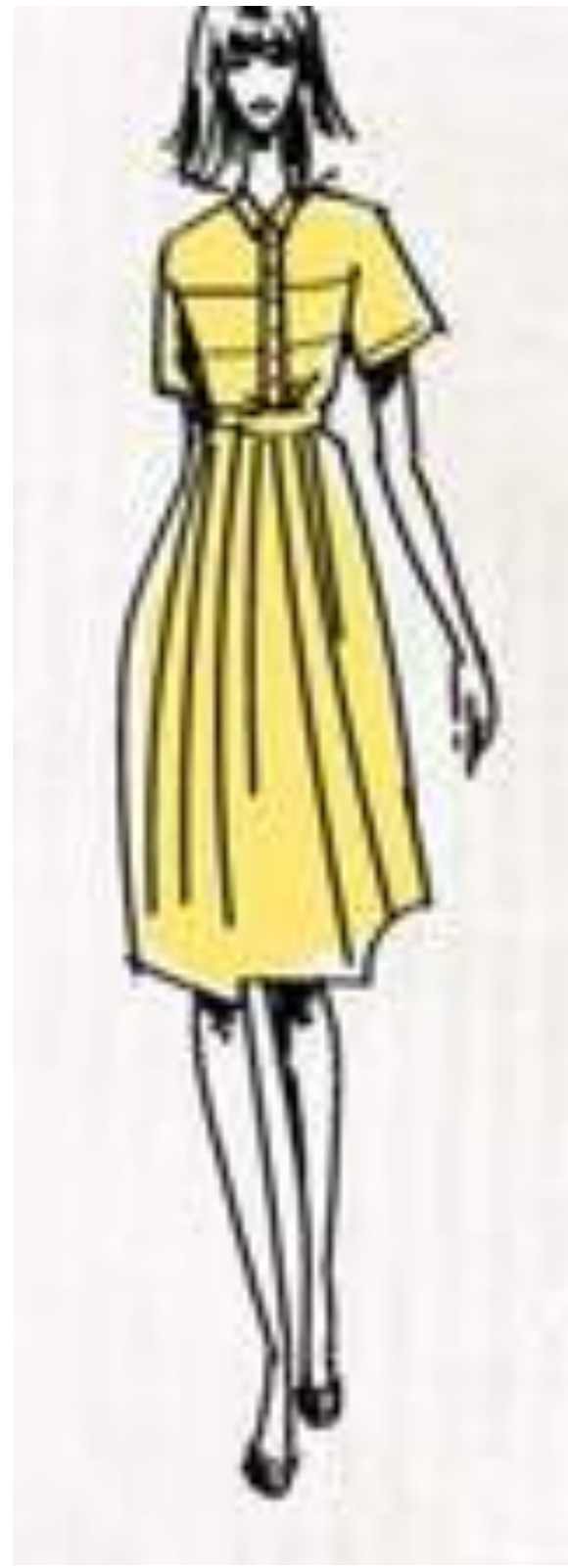


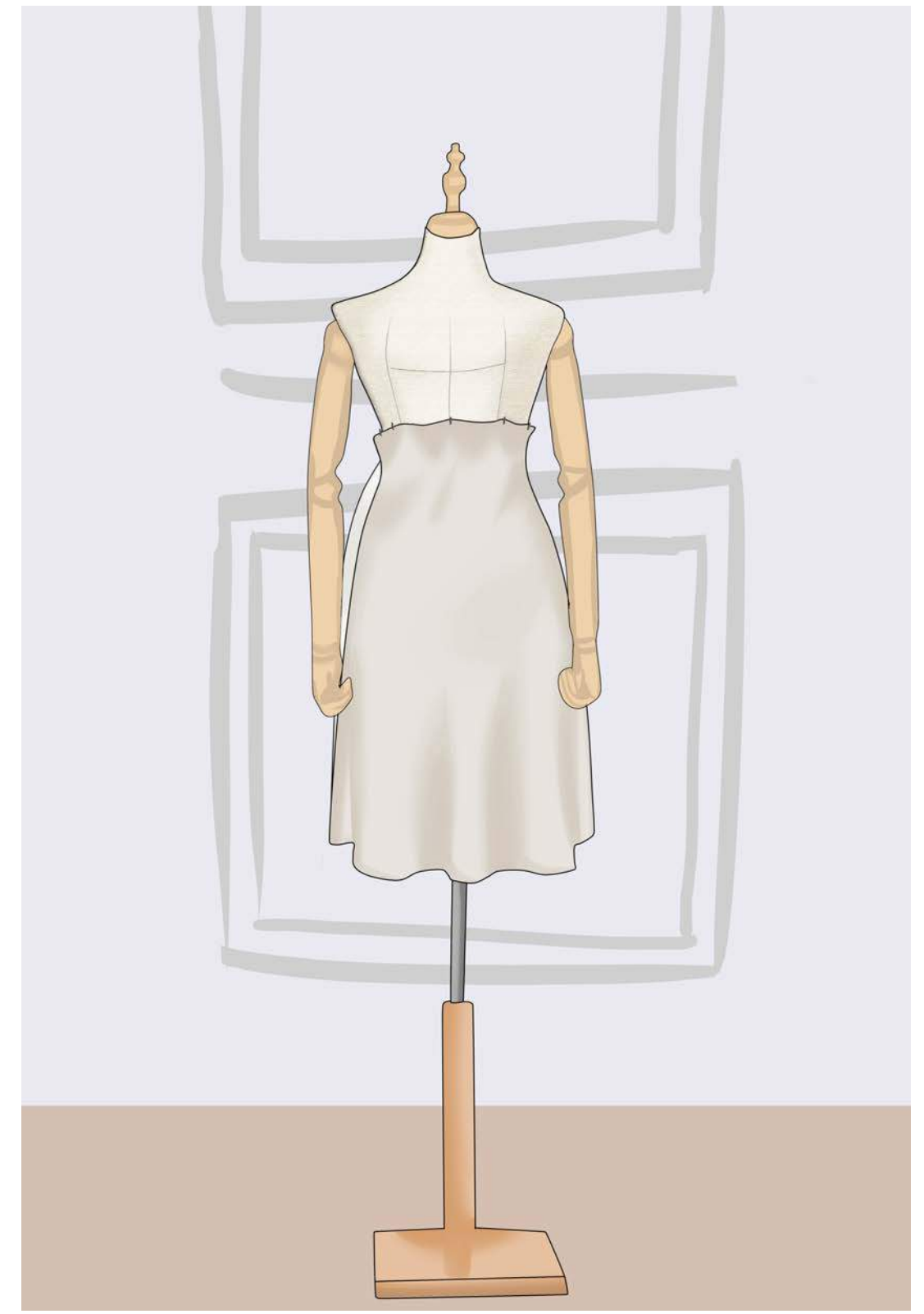
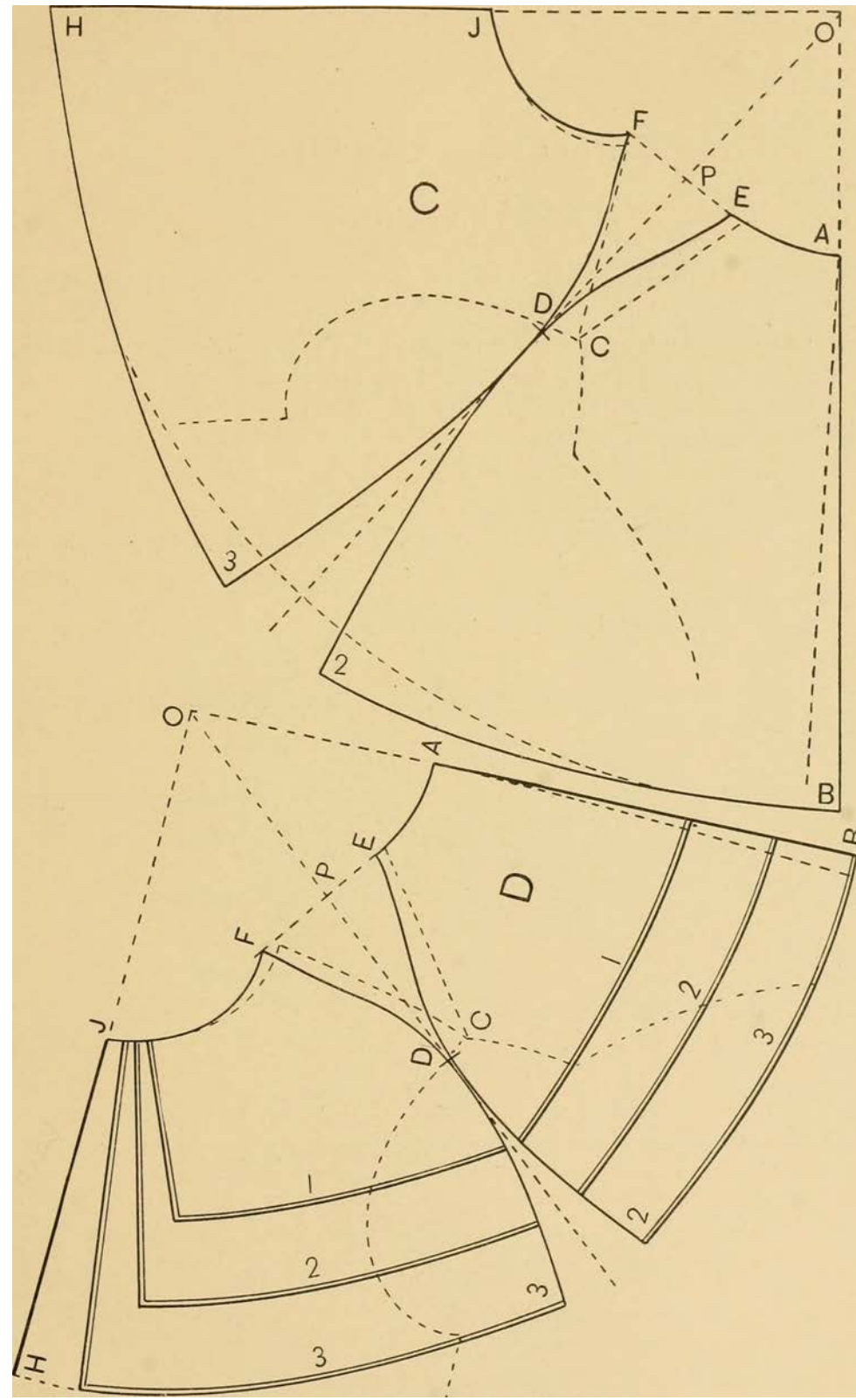
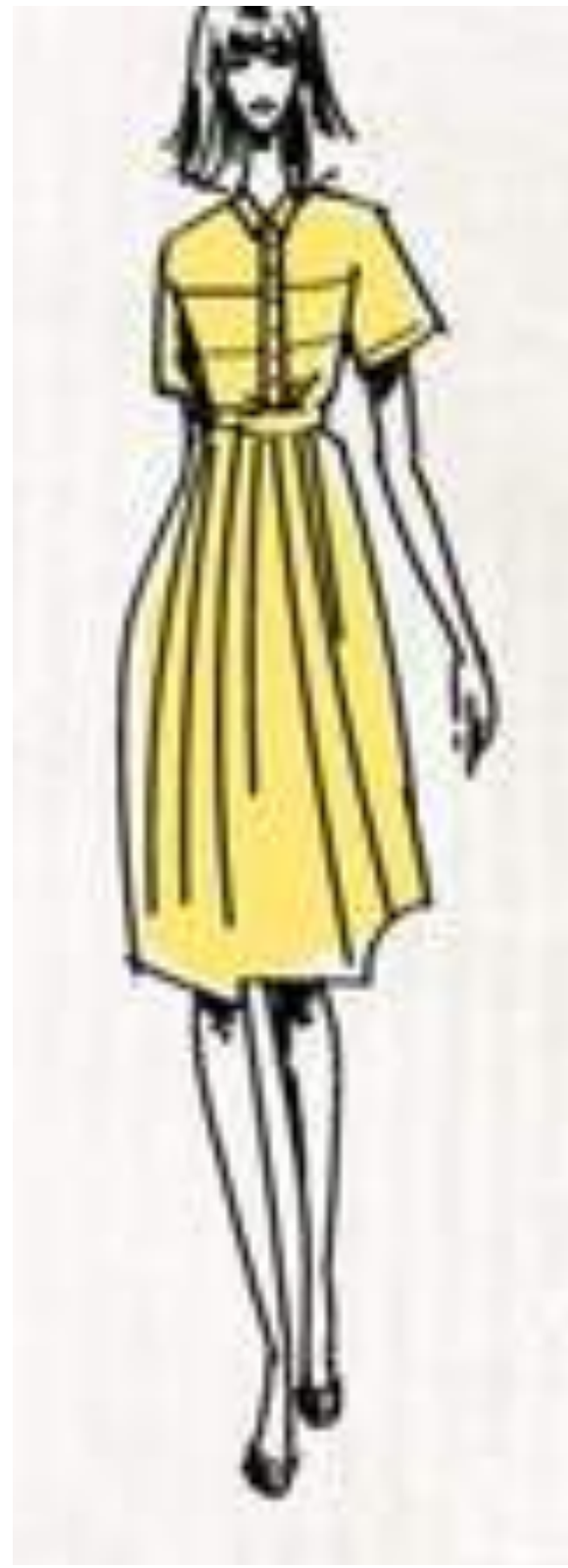
Jung et. al.

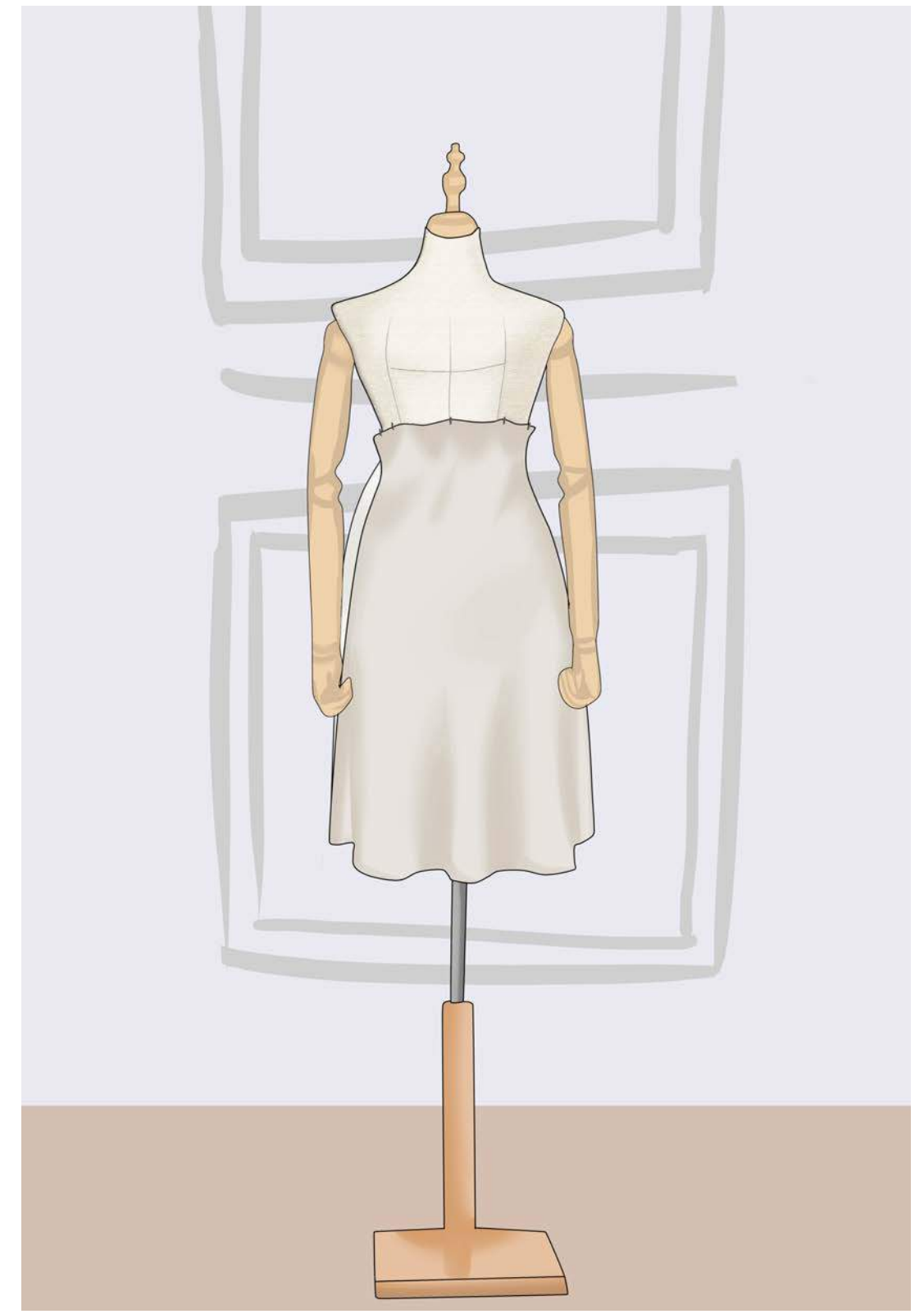
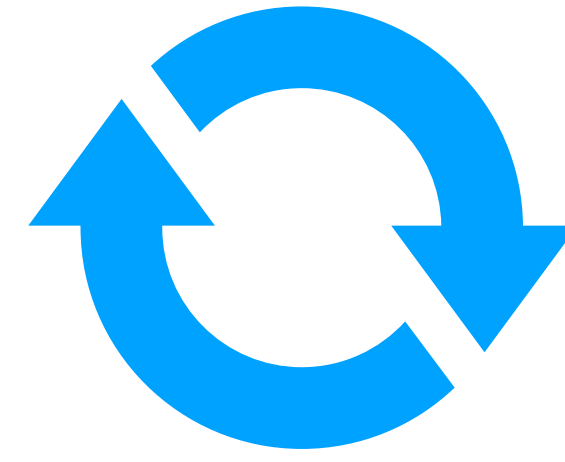
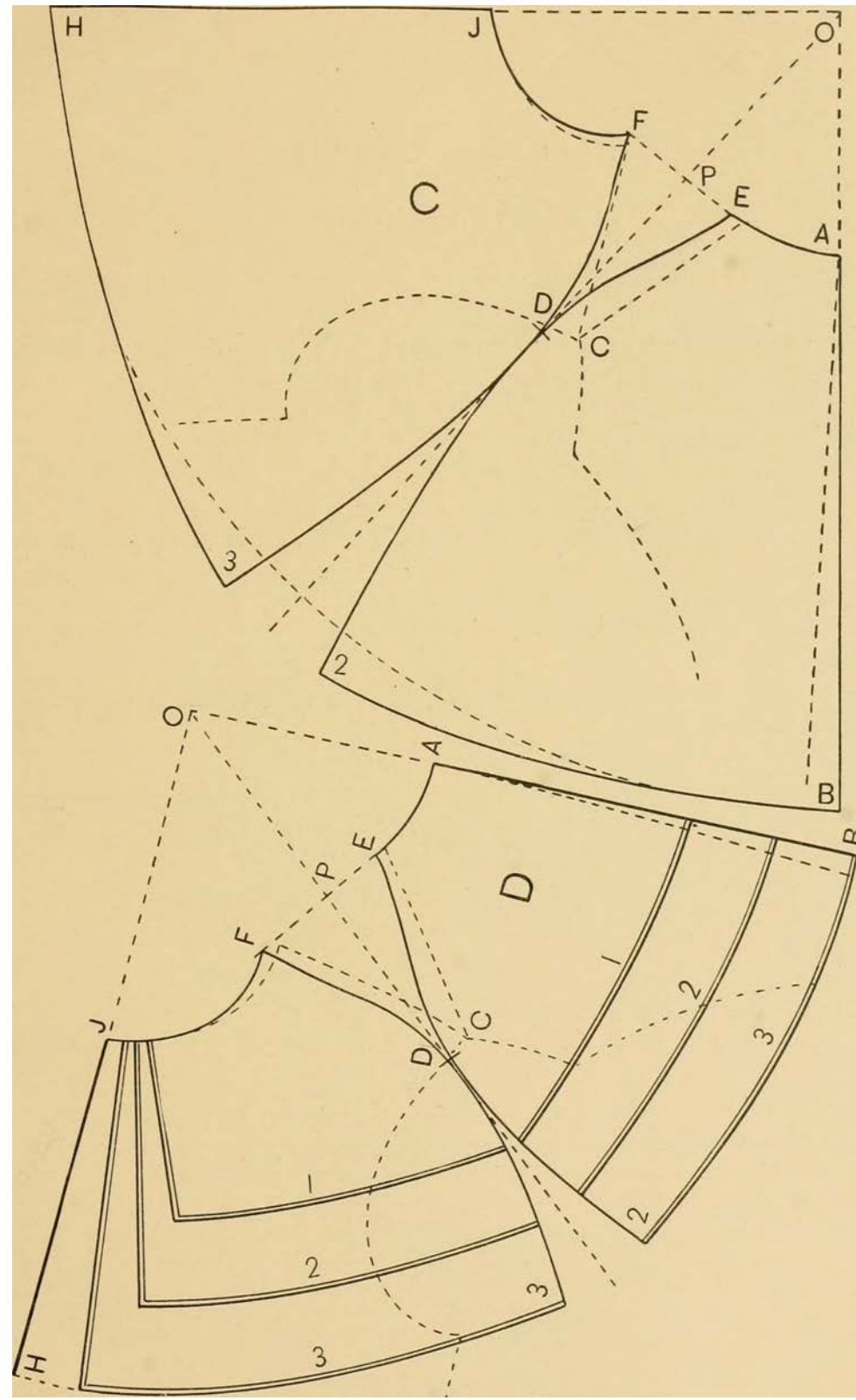
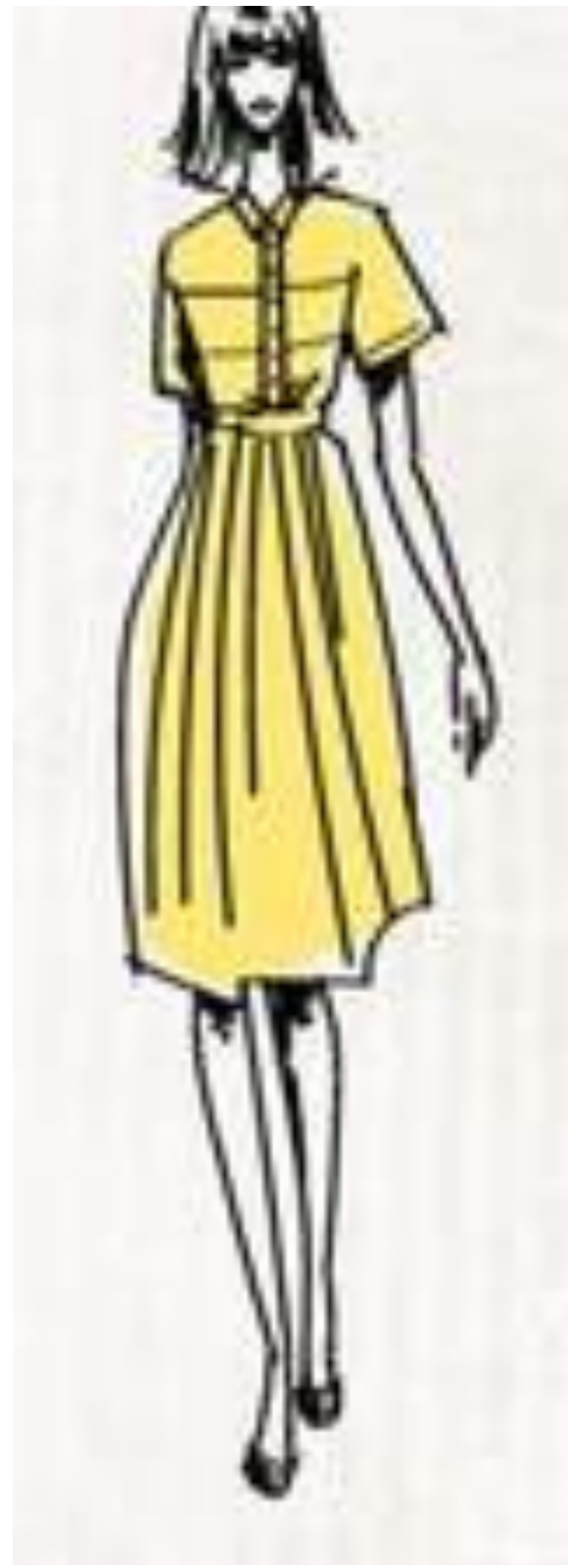


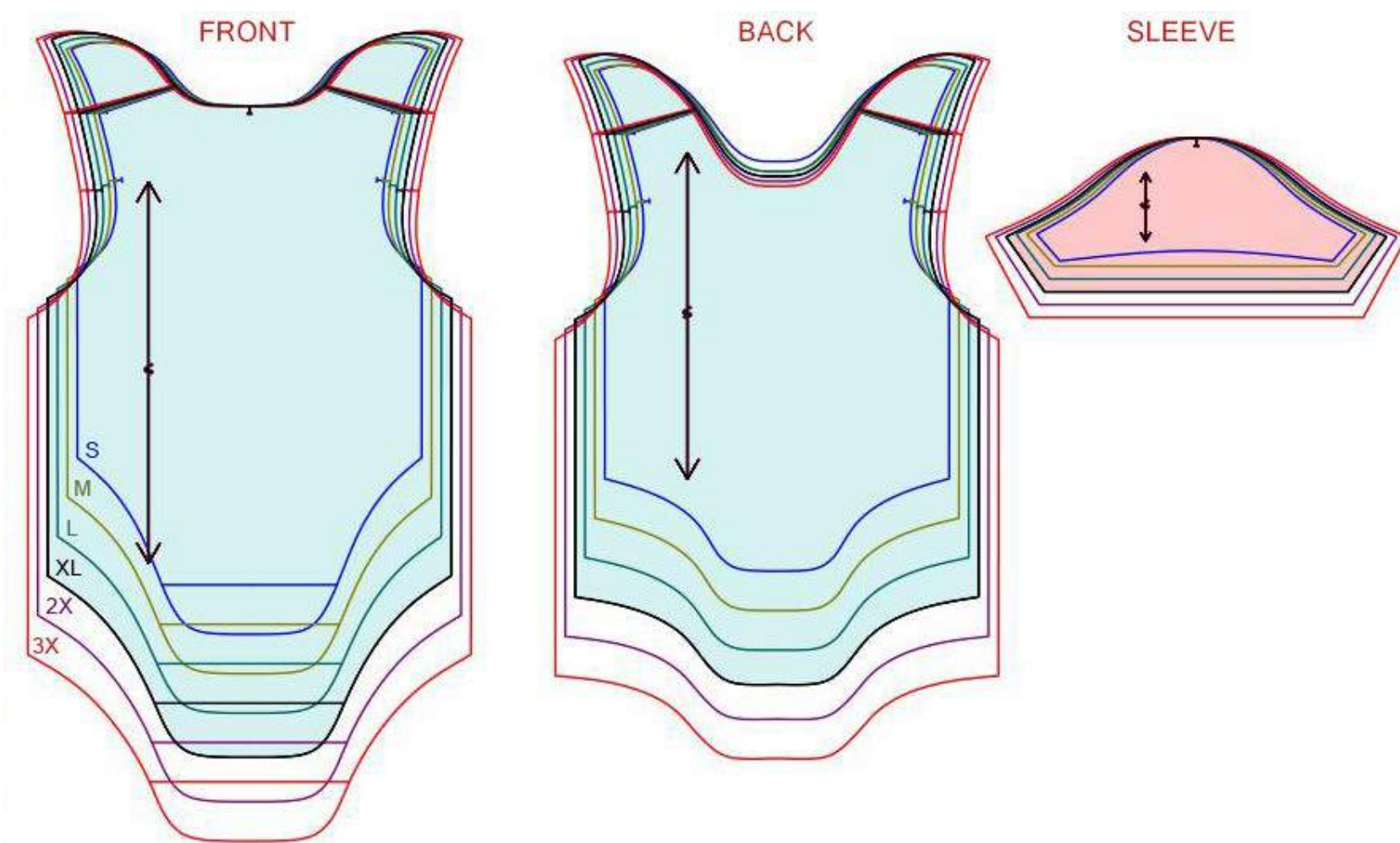
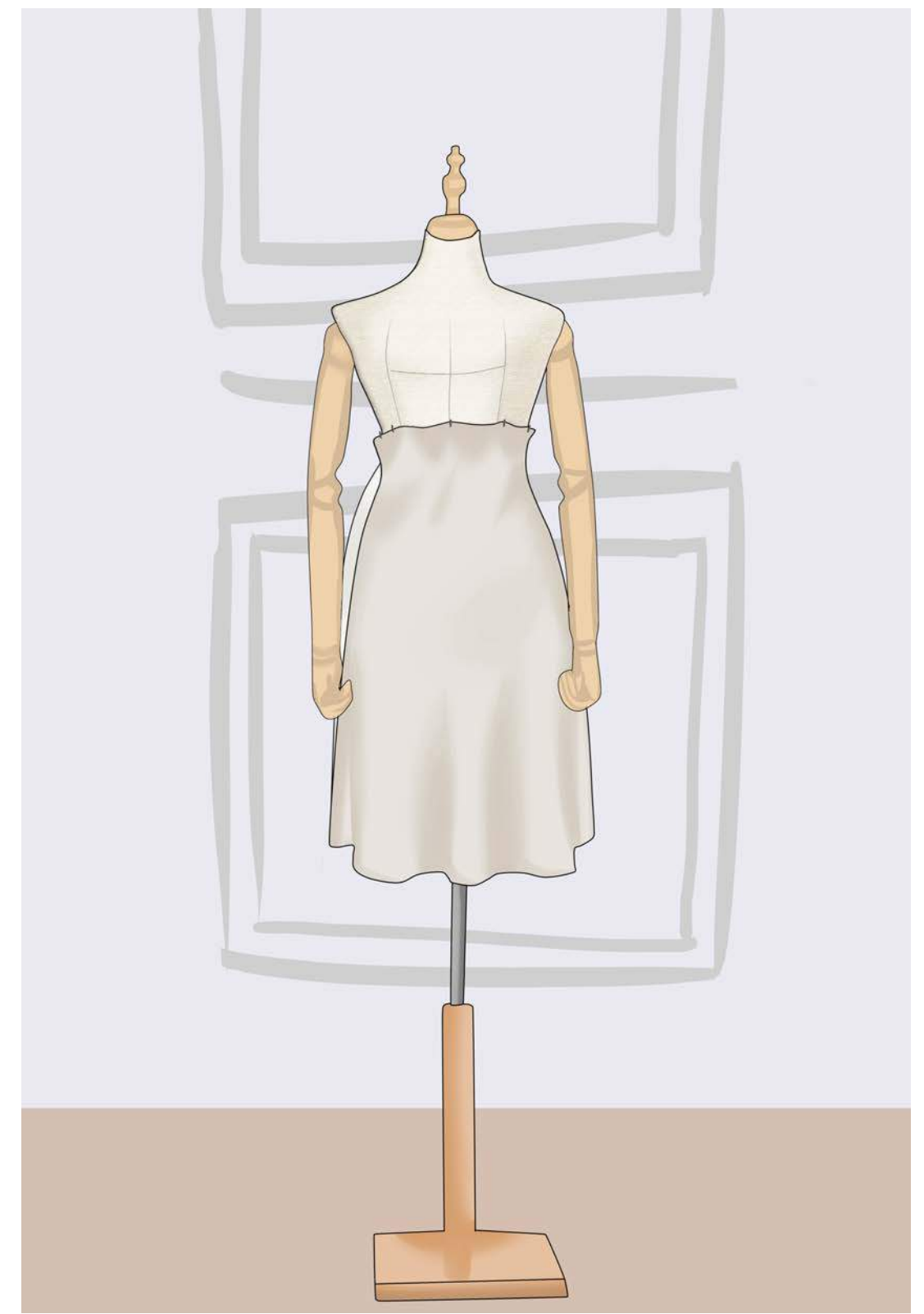
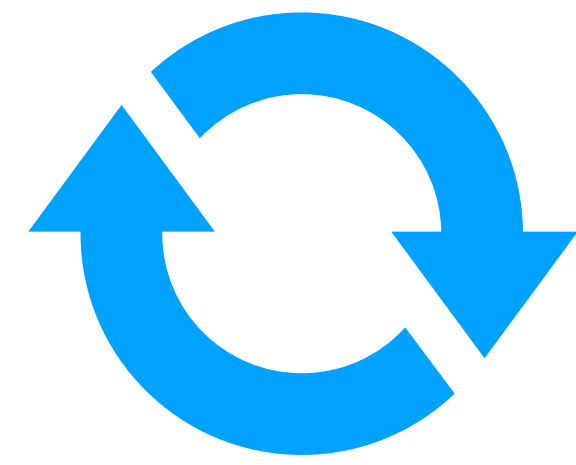
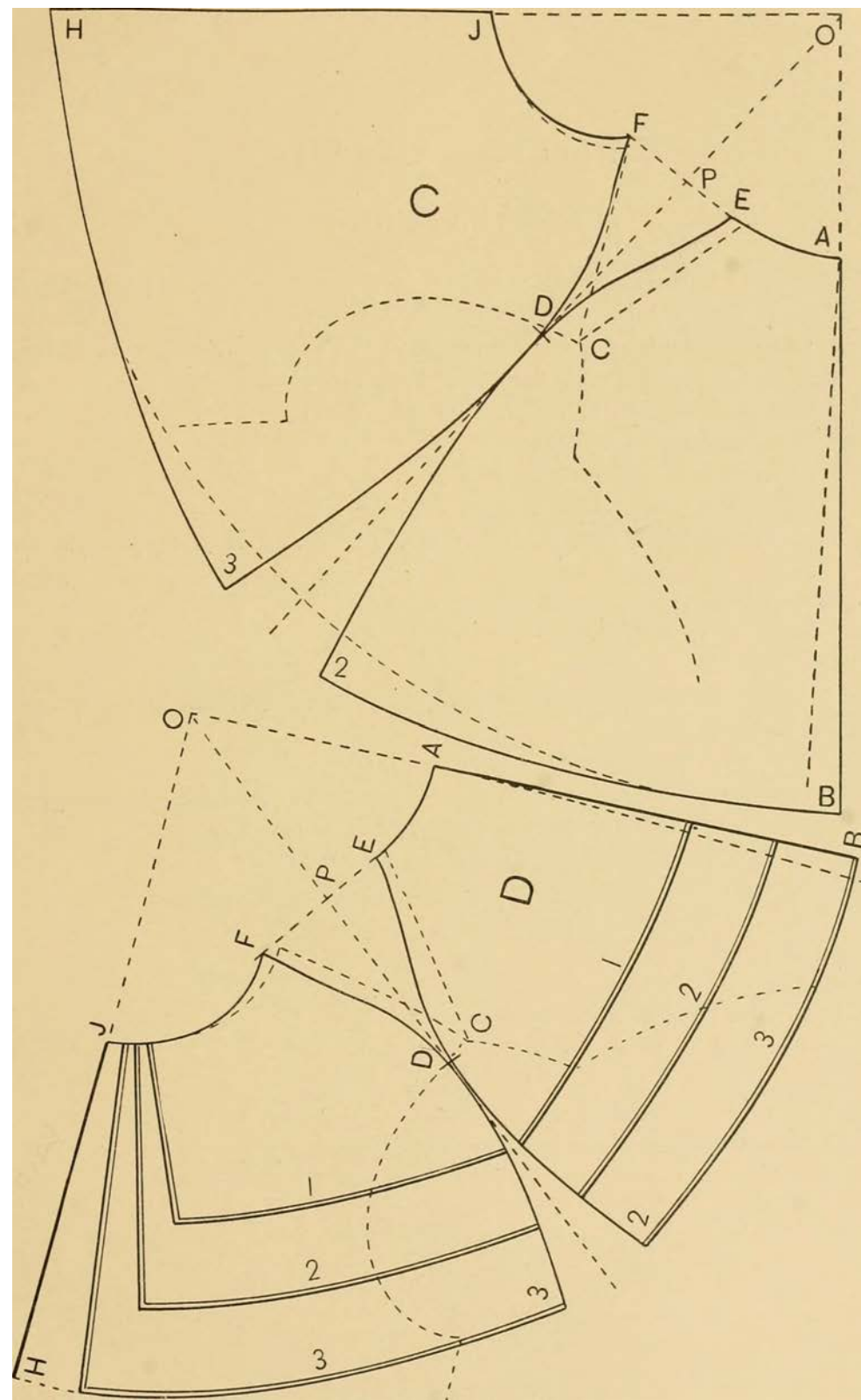
Bartle et. al. 2017

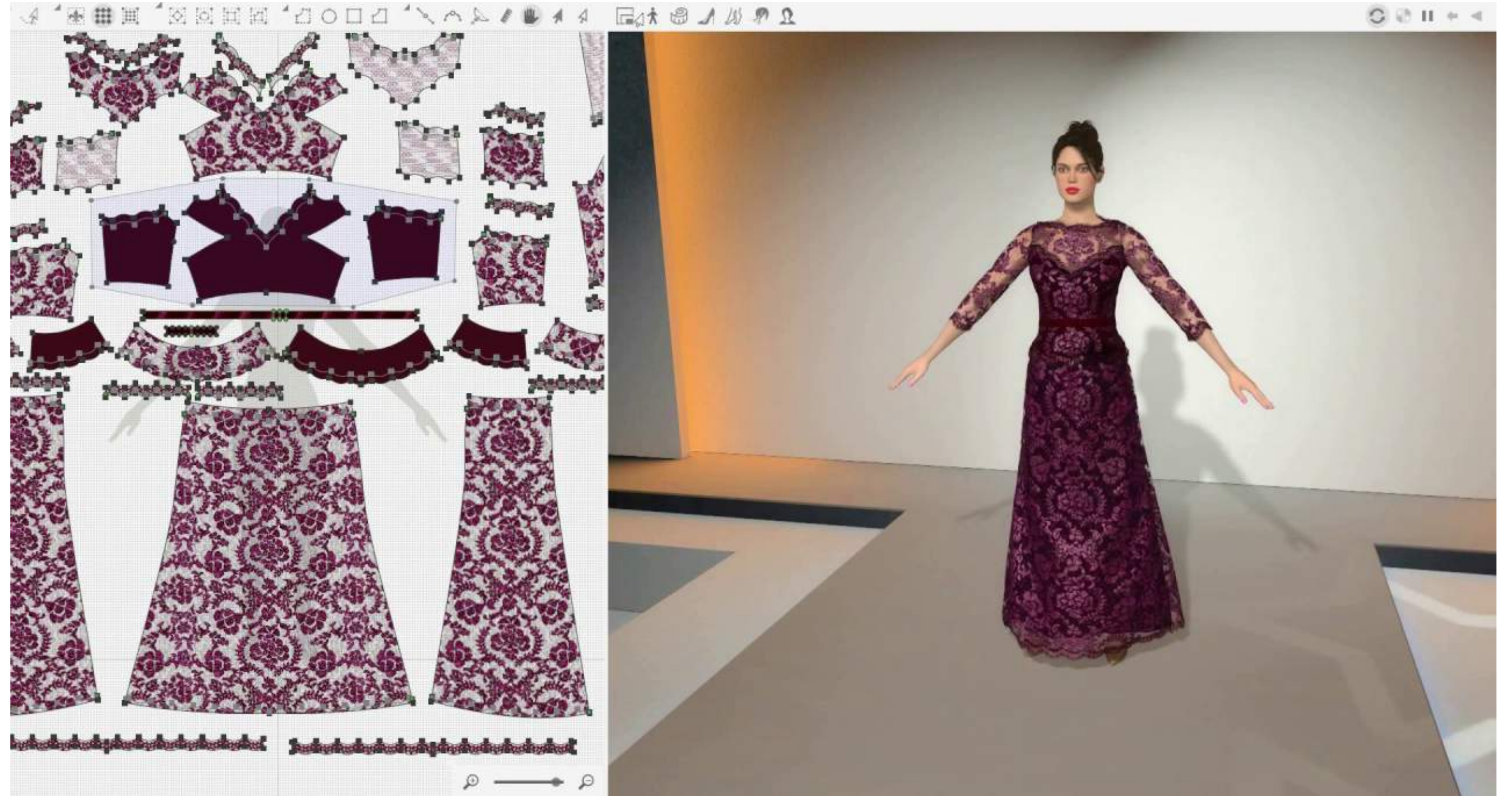












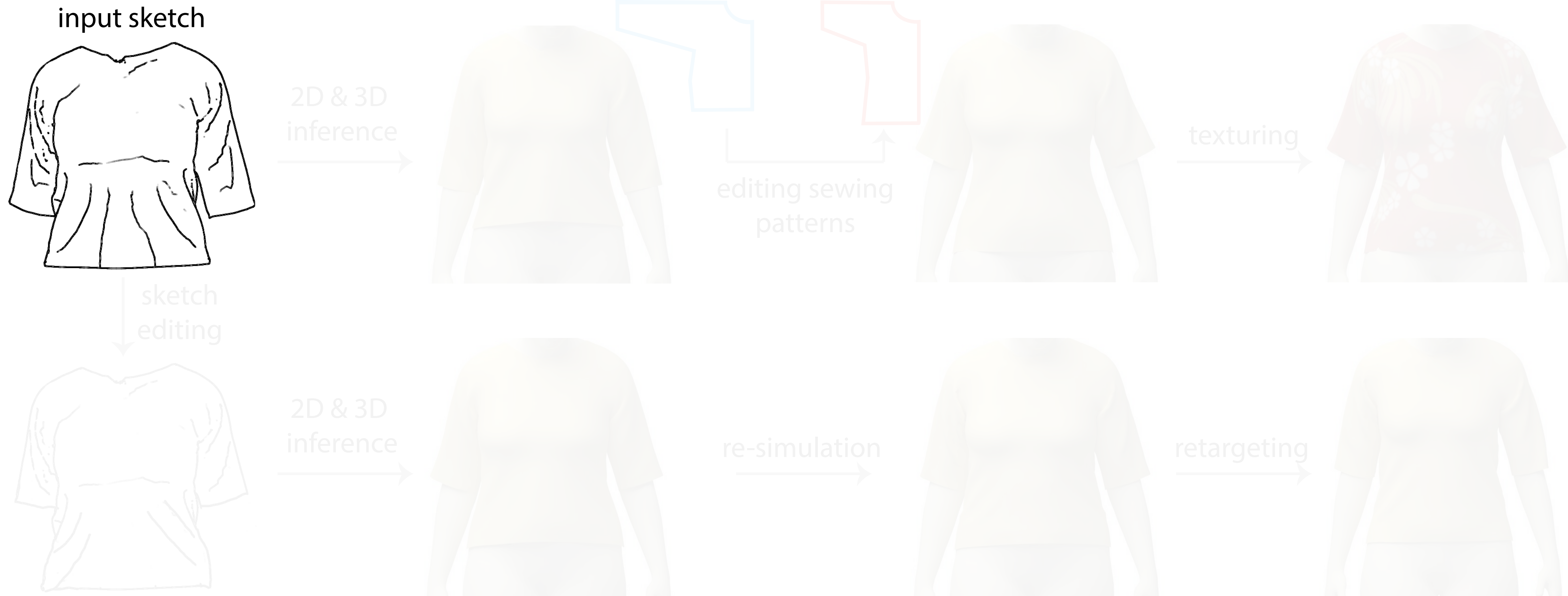


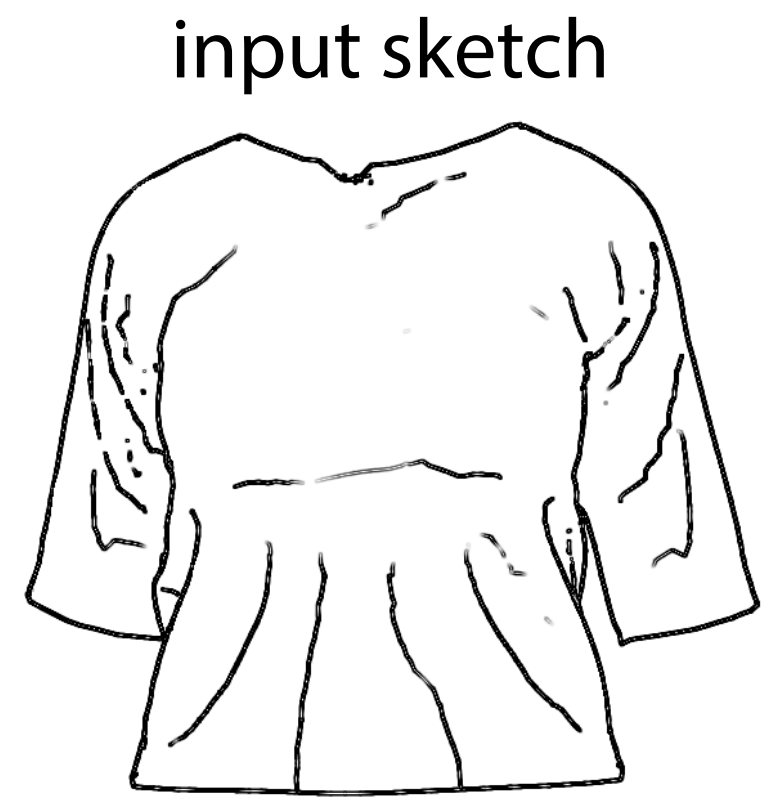
The screenshot displays a 3D fashion design software interface. The top portion shows a pattern layout for a long-sleeved gown, with various pieces of fabric marked with a red floral pattern. To the right, a 3D model of a woman wearing the finished purple lace gown is shown in a virtual environment. The bottom portion of the interface features a technical drawing window titled "Auto Design" with a size specification table.

Auto Design

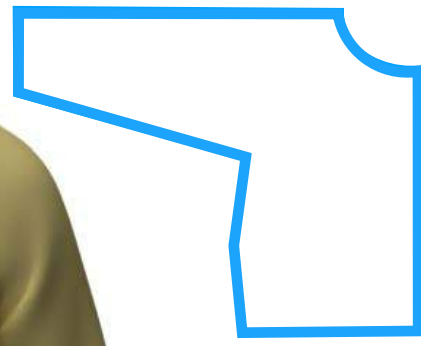
Style: 衬衫短袖
 Size: [dropdown]
 Dispersion: 1
 Preview: [slider]
 Ok Cancel

	M	L
衣长	74	75
胸围	108	108
腰围	102	102
摆围	104	104
肩宽	45.5	45.5
腰节	42	42
袖长	22	22





2D & 3D
inference



editing sewing
patterns



texturing



sketch
editing



2D & 3D
inference

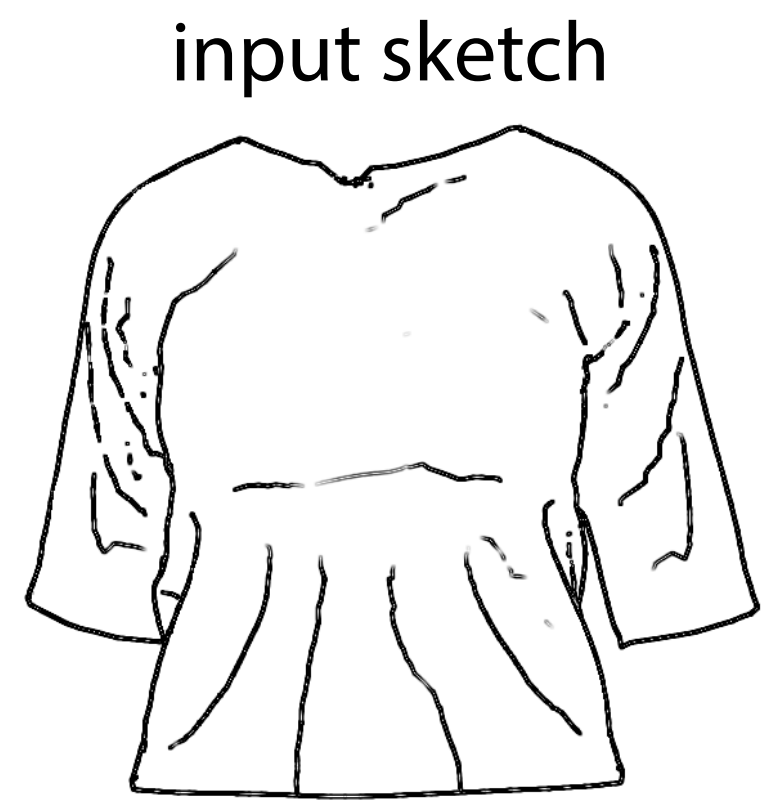


re-simulation

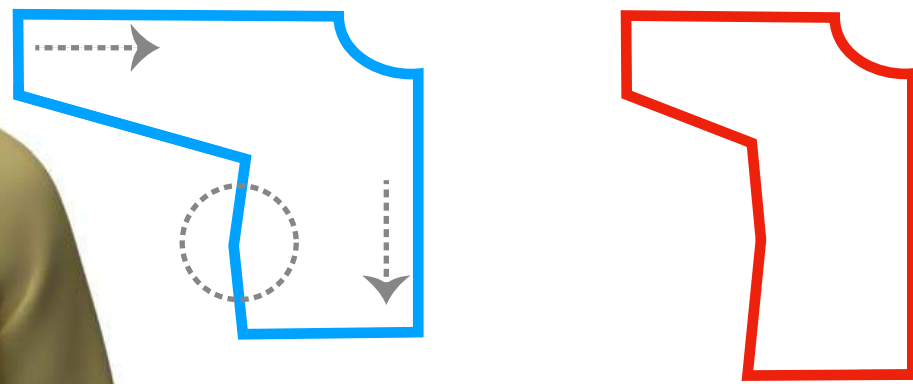


retargeting





2D & 3D inference



editing sewing patterns



texturing



sketch editing



2D & 3D inference

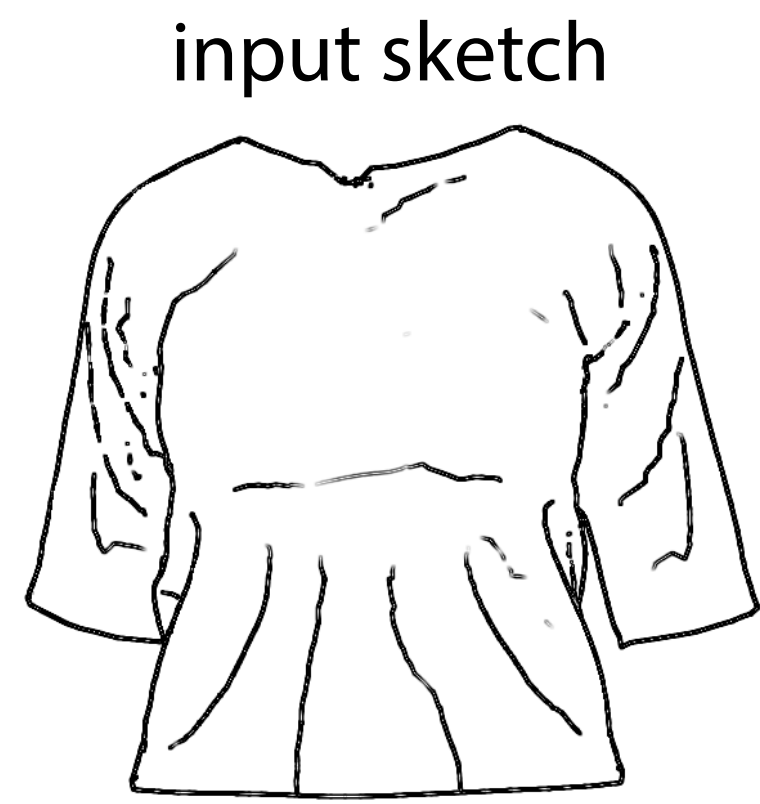


re-simulation

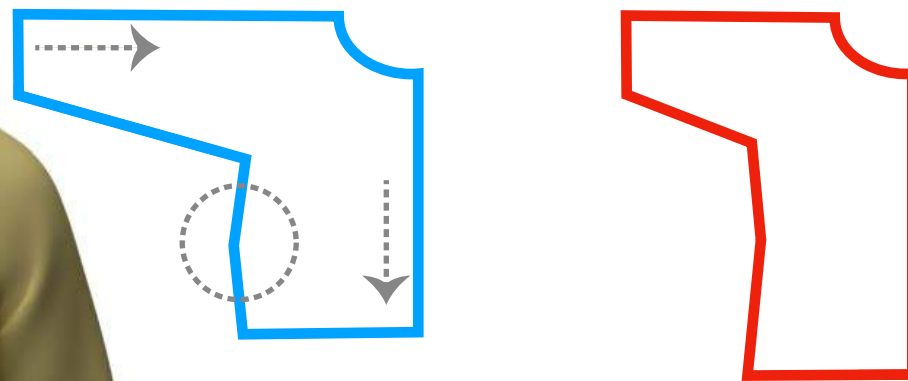


retargeting





2D & 3D
inference



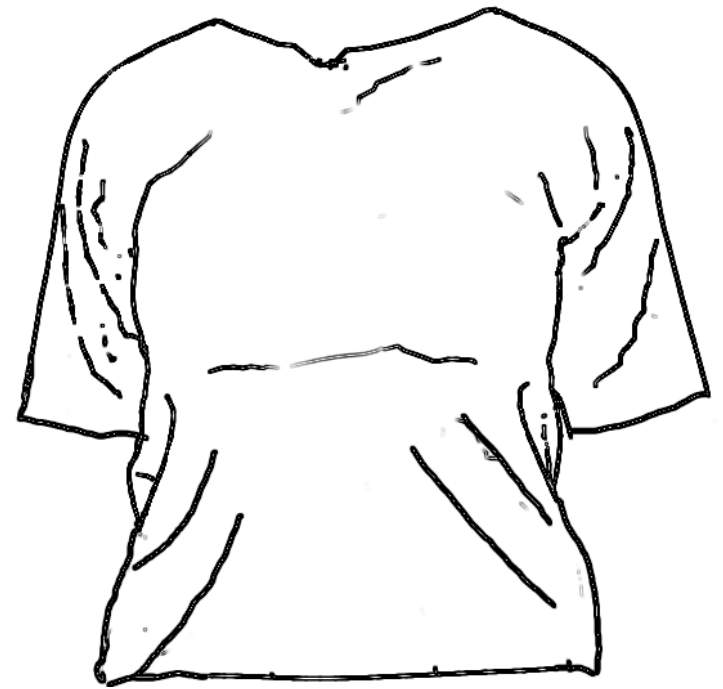
editing sewing
patterns



texturing



sketch
editing



2D & 3D
inference

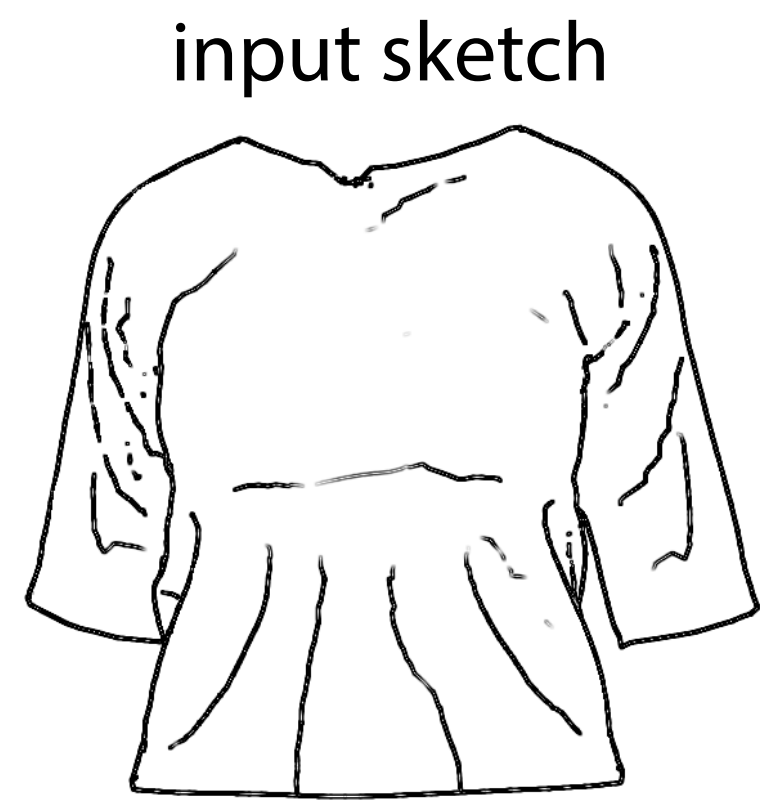


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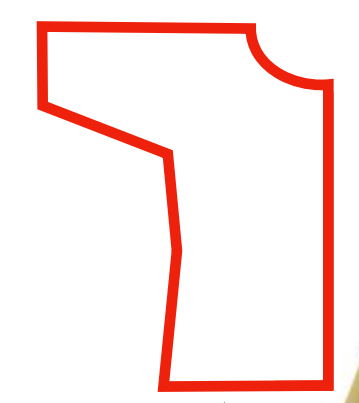
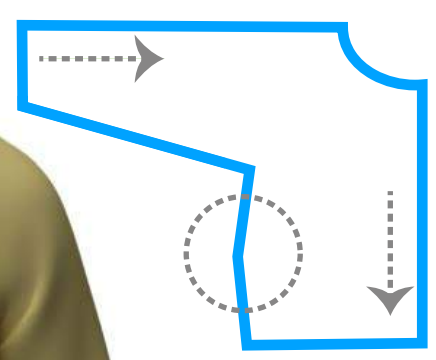


retargeting





2D & 3D inference



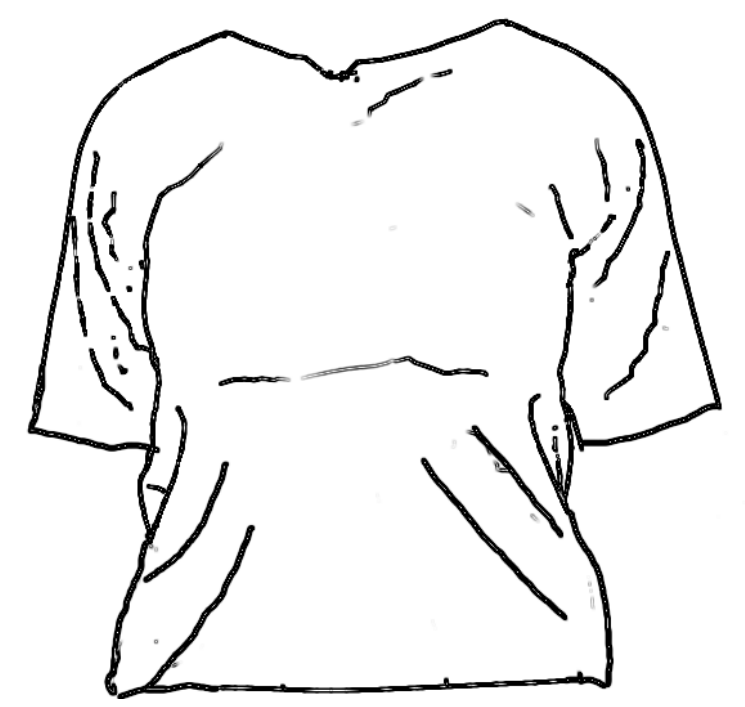
editing sewing patterns



texturing



sketch editing



2D & 3D inference

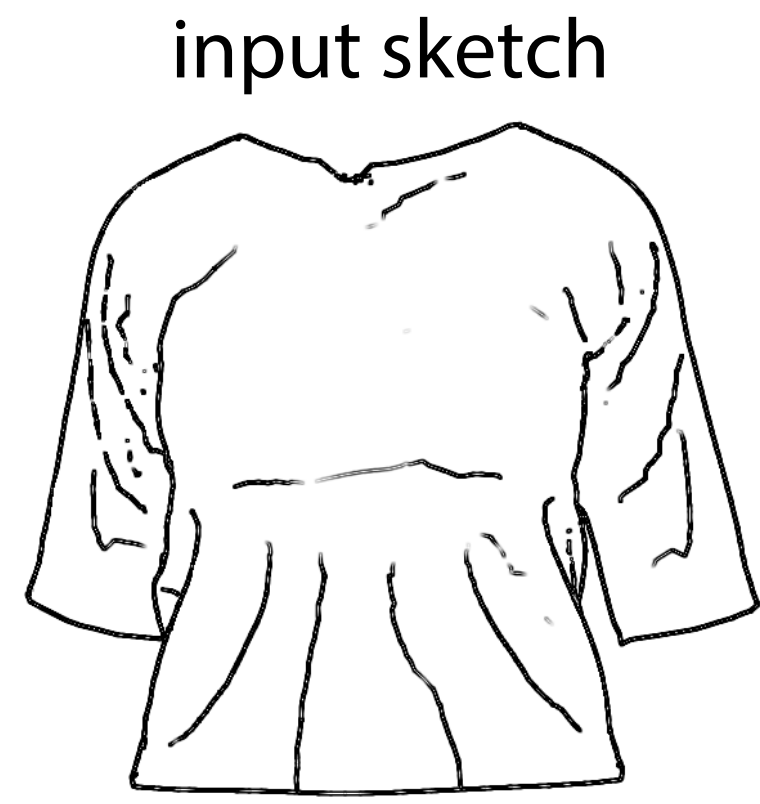


re-simulation

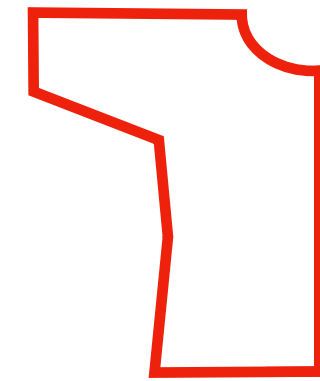
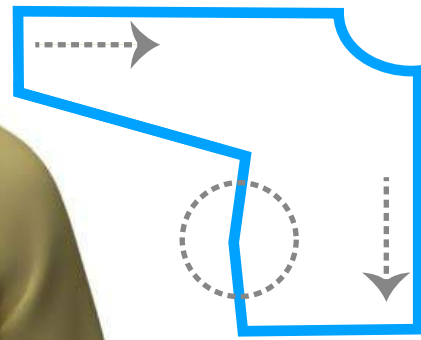


retargeting





2D & 3D inference



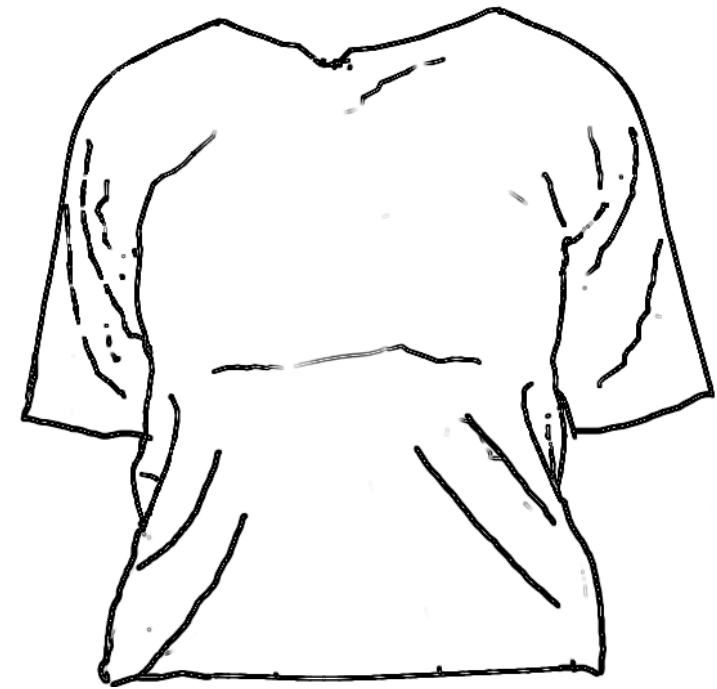
editing sewing patterns



texturing



sketch editing



2D & 3D inference

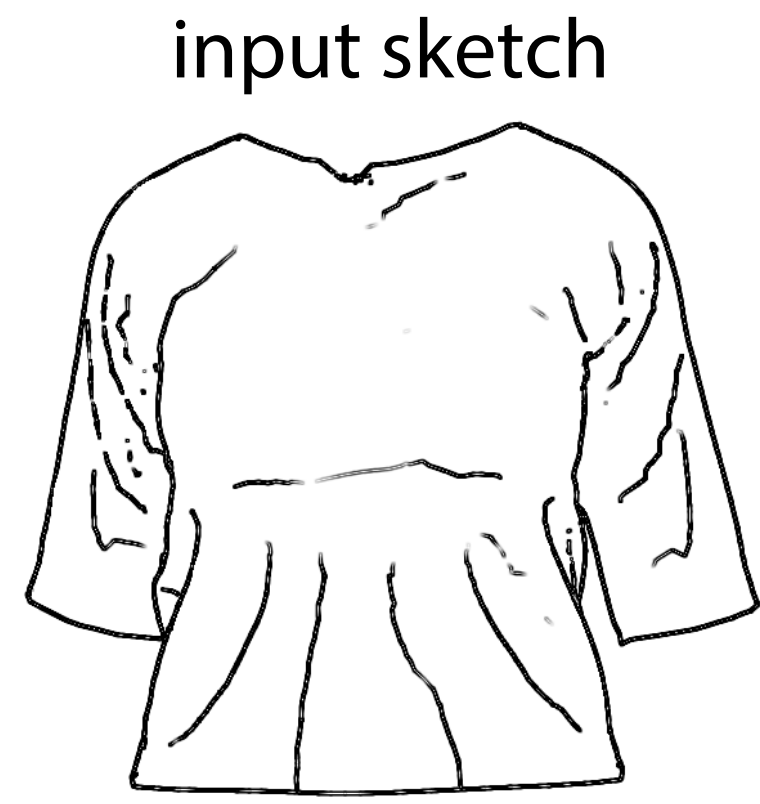


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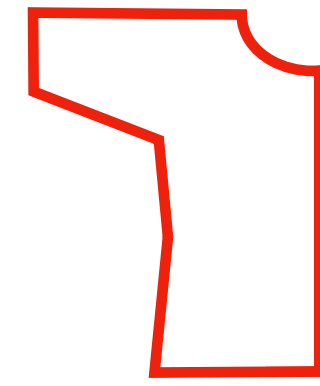
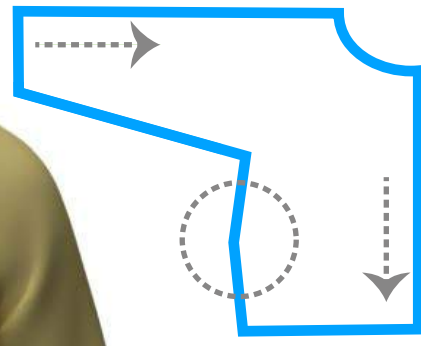


retargeting





2D & 3D inference



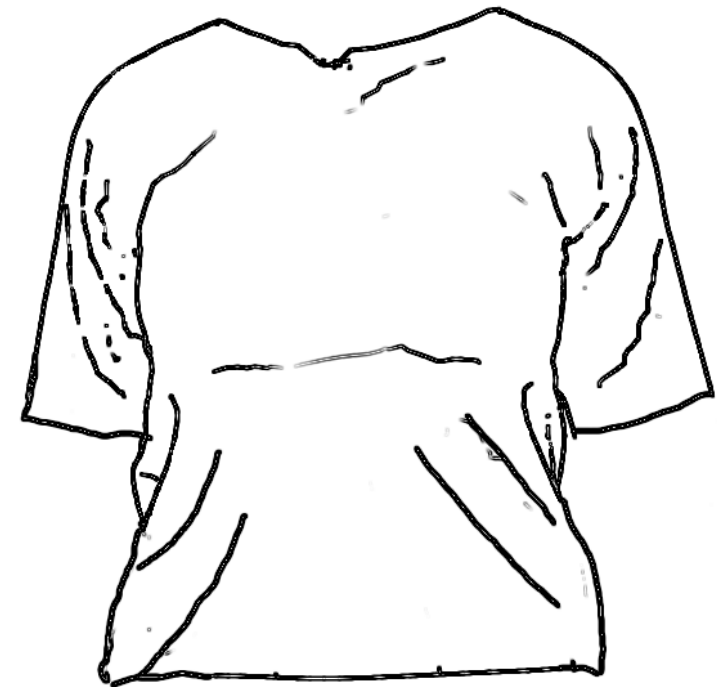
editing sewing patterns



texturing



sketch editing



2D & 3D inference

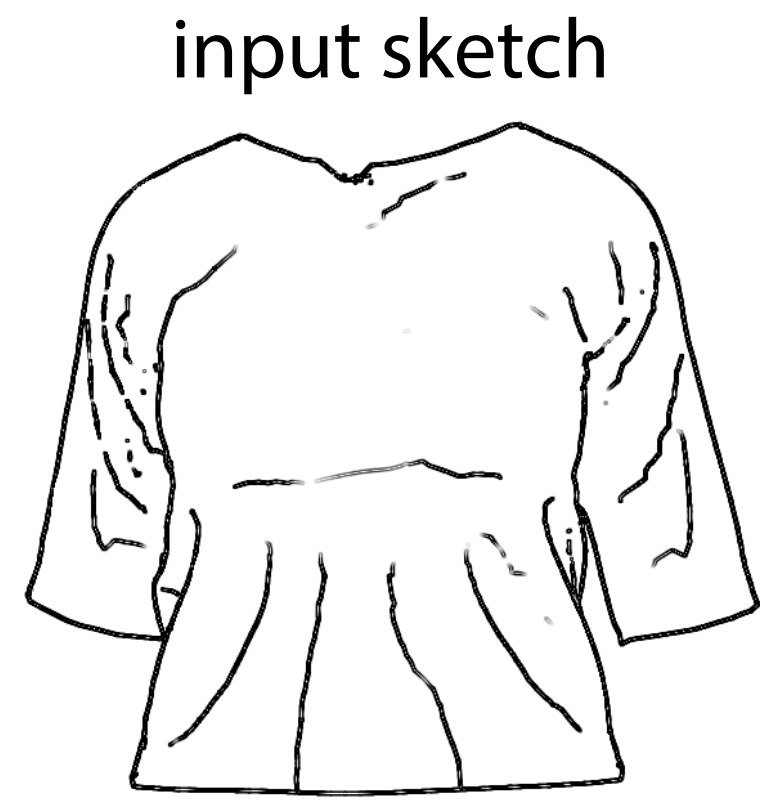


re-simulation

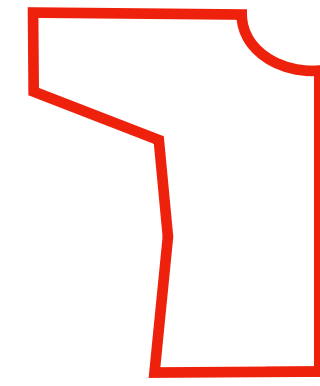
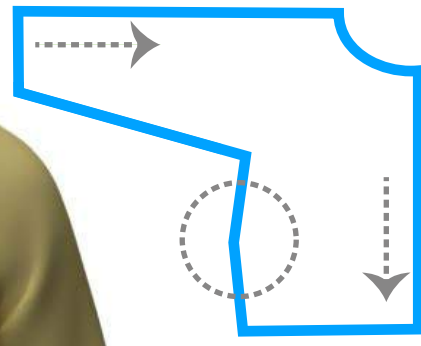


retargeting





2D & 3D inference



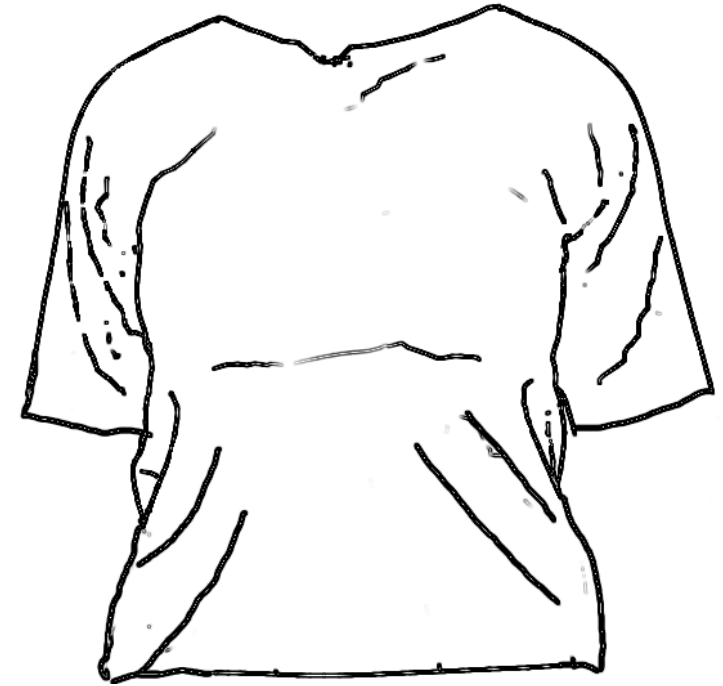
editing sewing patterns



texturing



sketch editing



2D & 3D inference

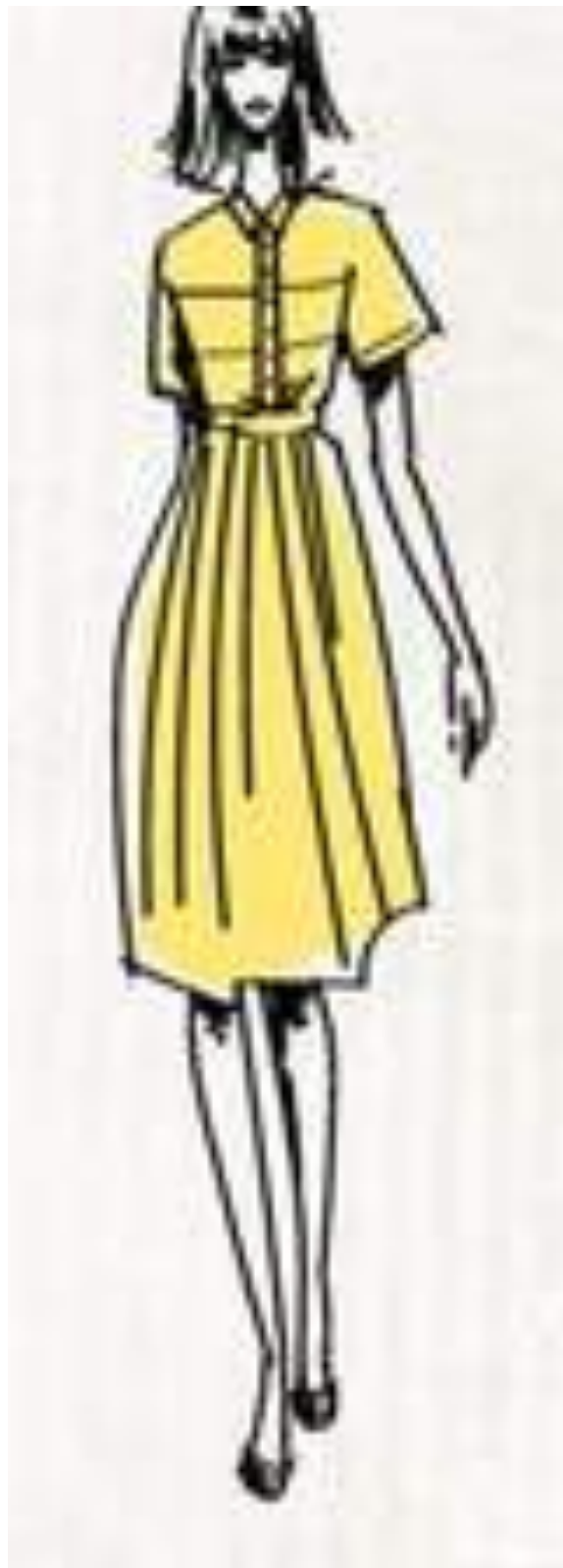


re-simulation

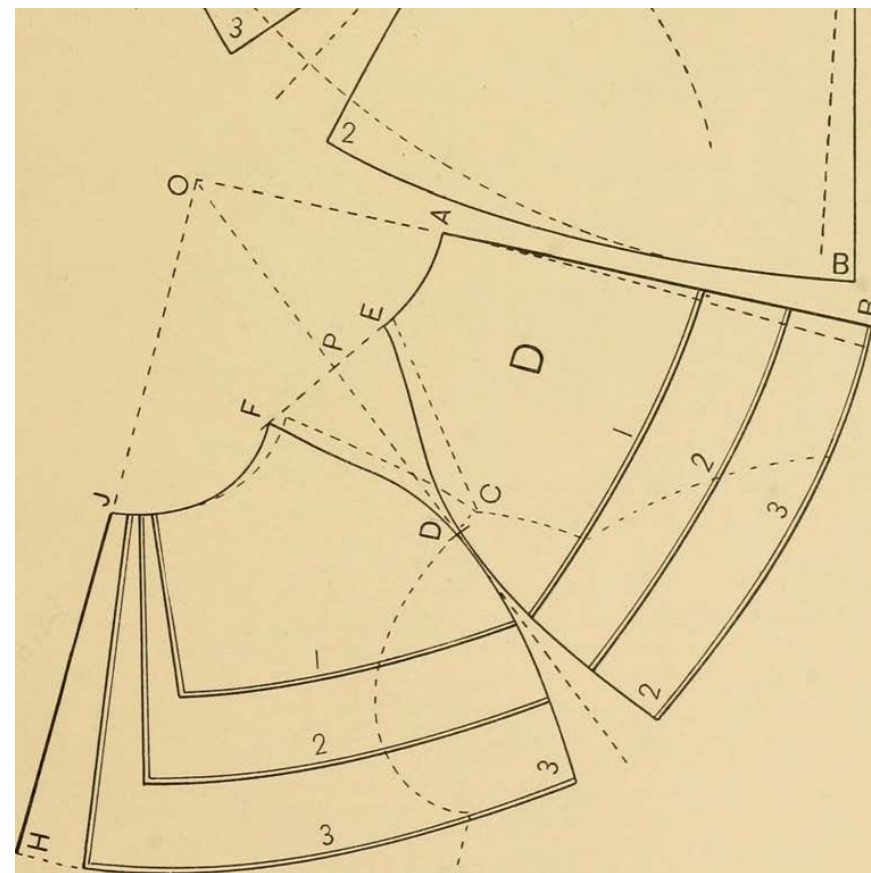
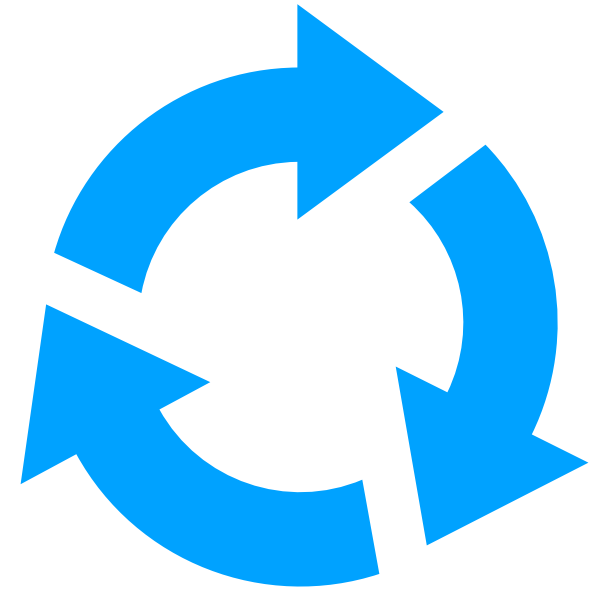


retargeting





2D Sketch



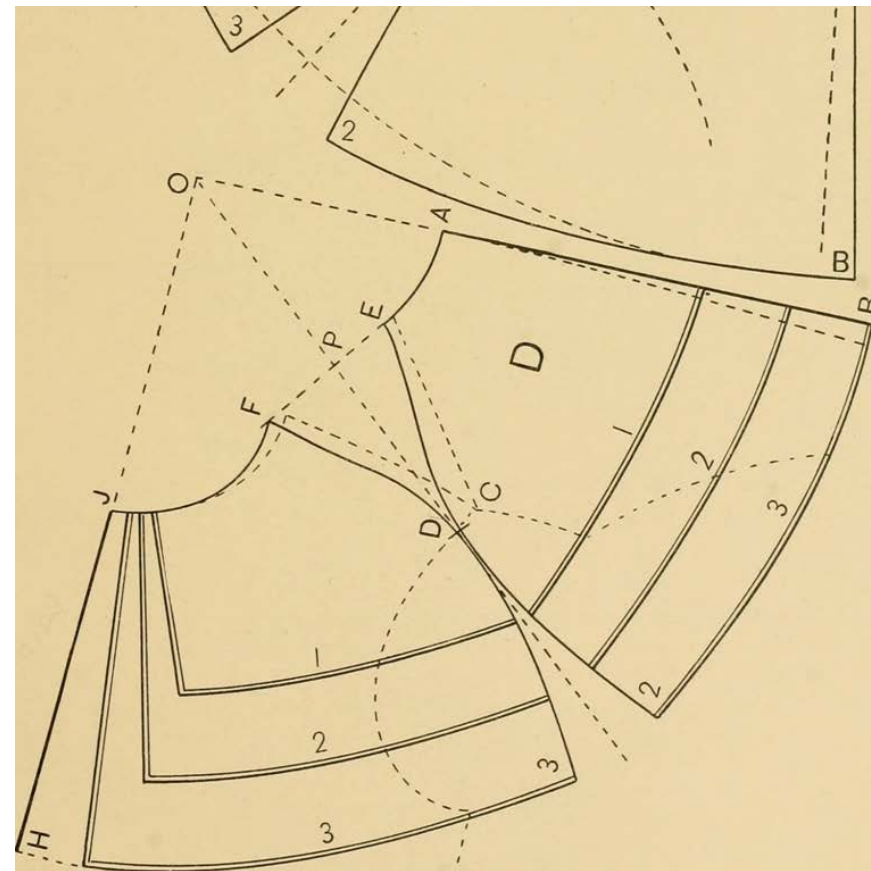
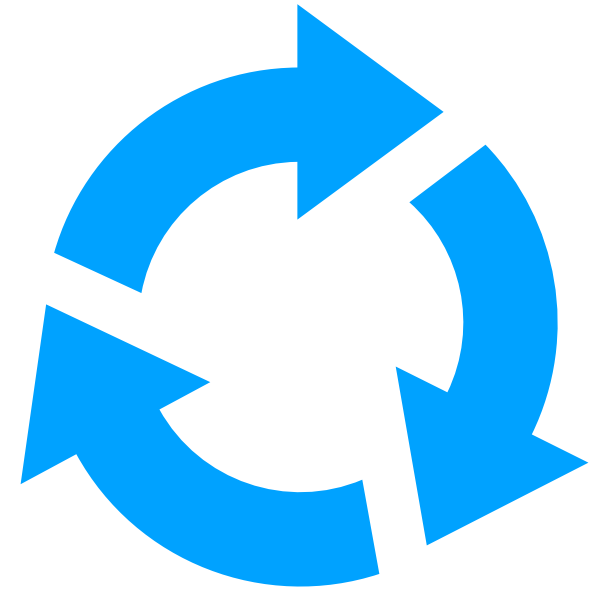
Sewing pattern



3D shape



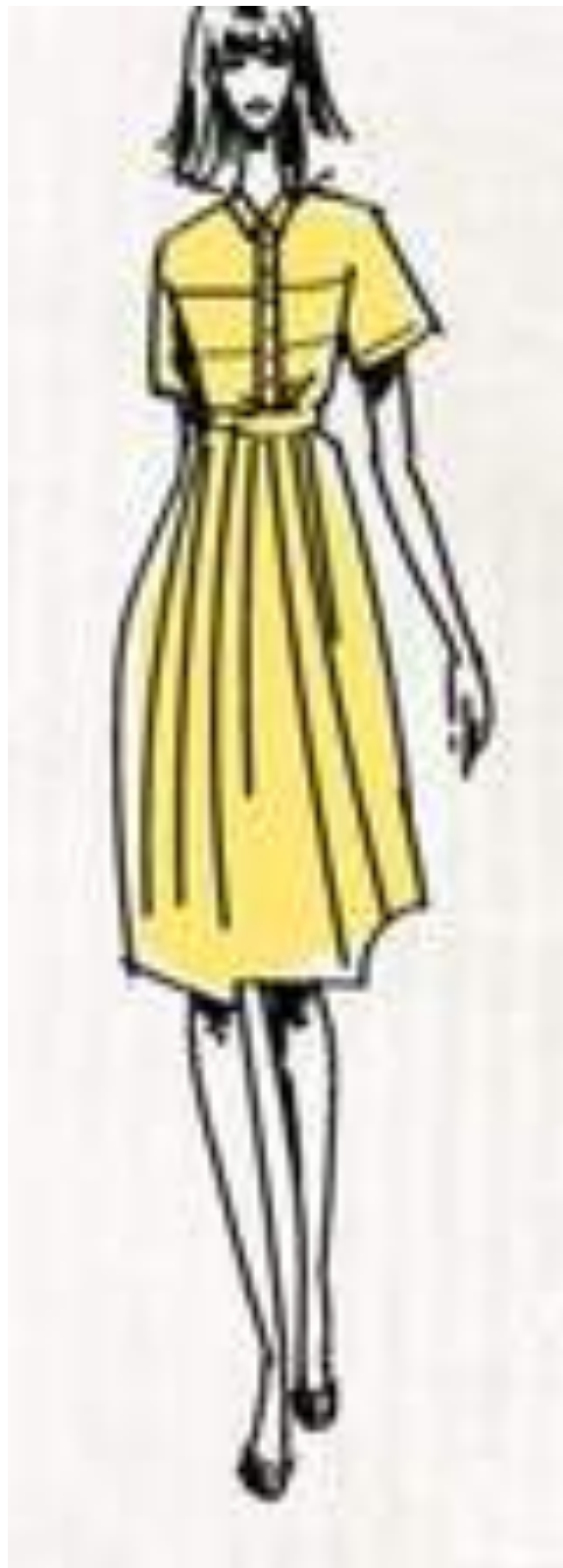
2D Sketch



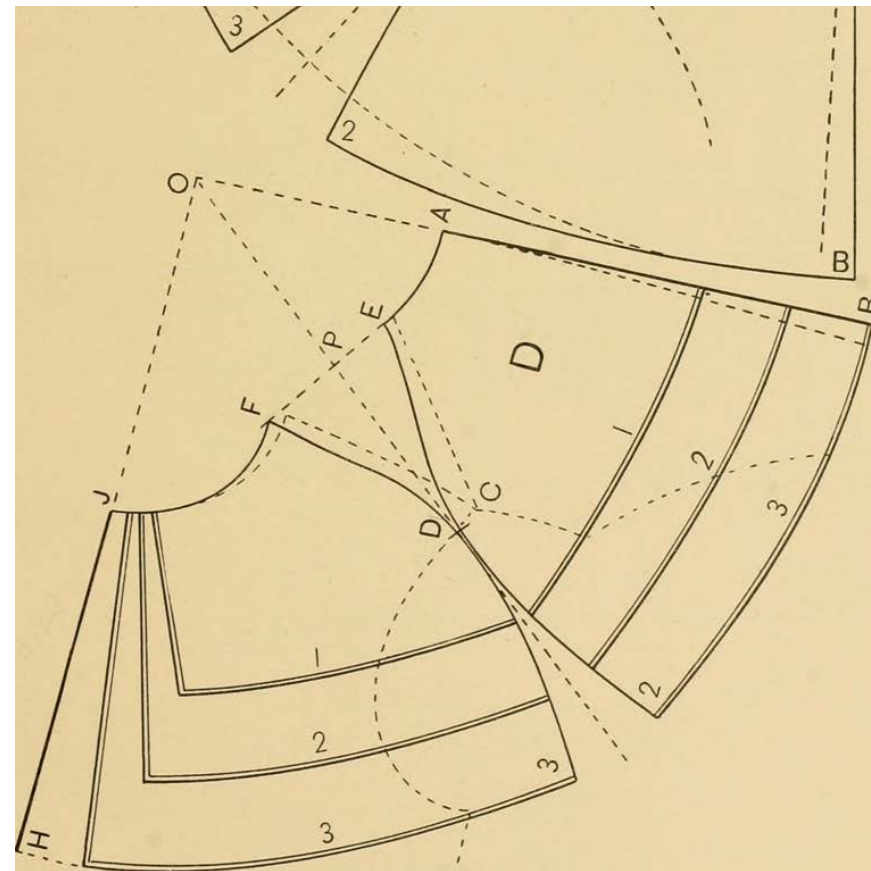
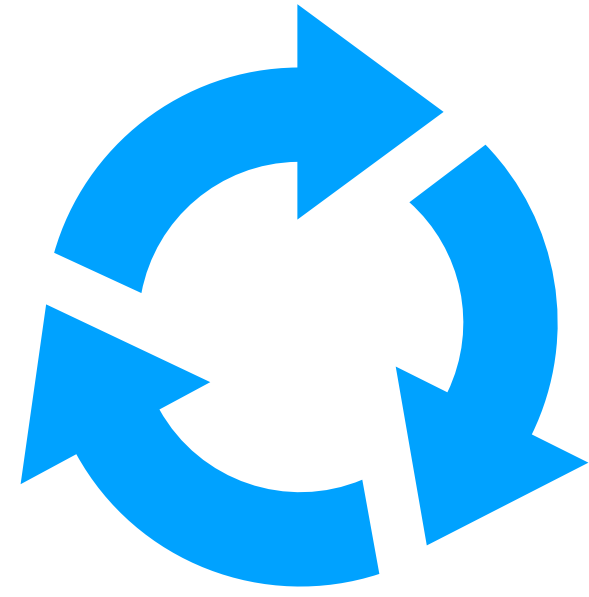
Sewing pattern



3D shape



2D Sketch



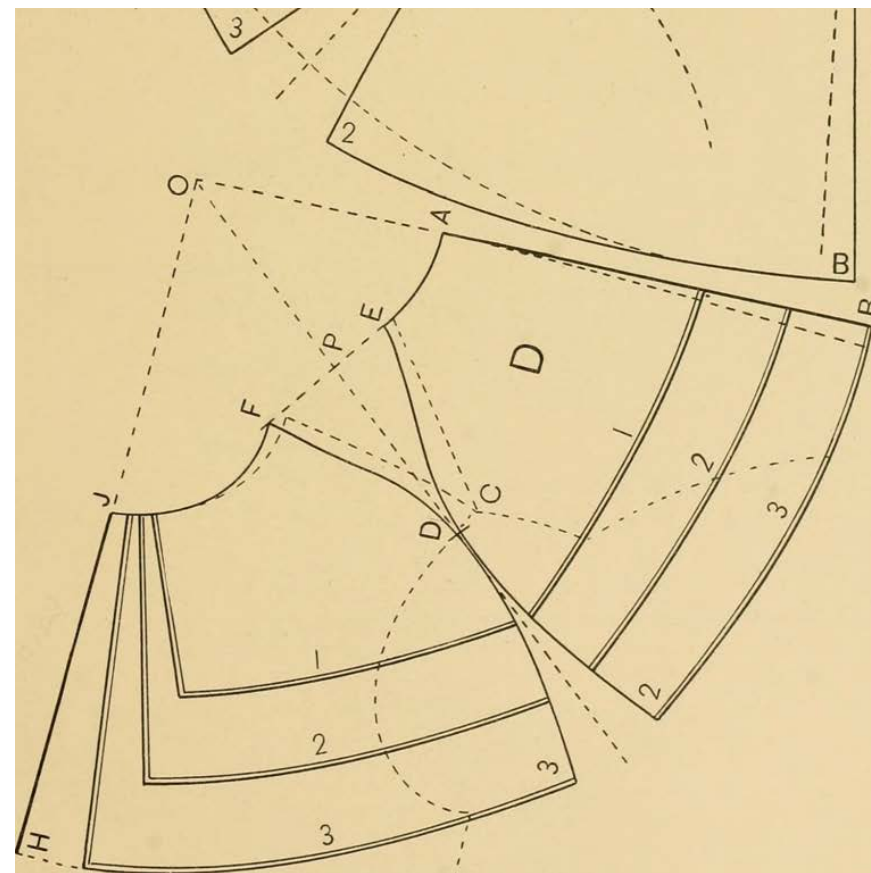
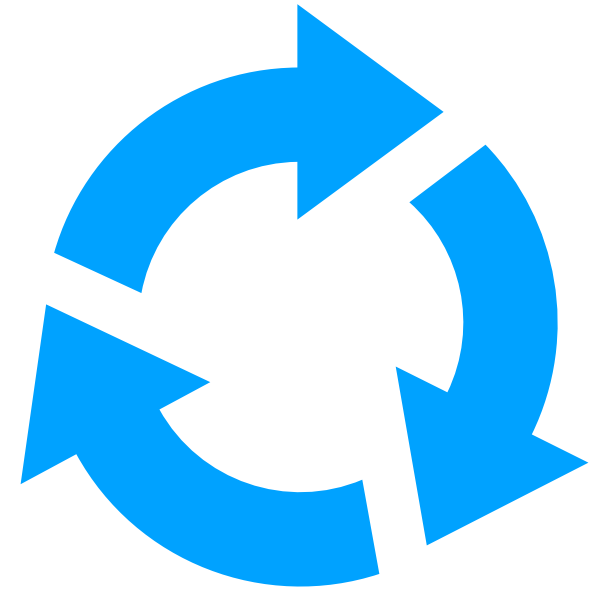
Sewing pattern



3D shape



2D Sketch



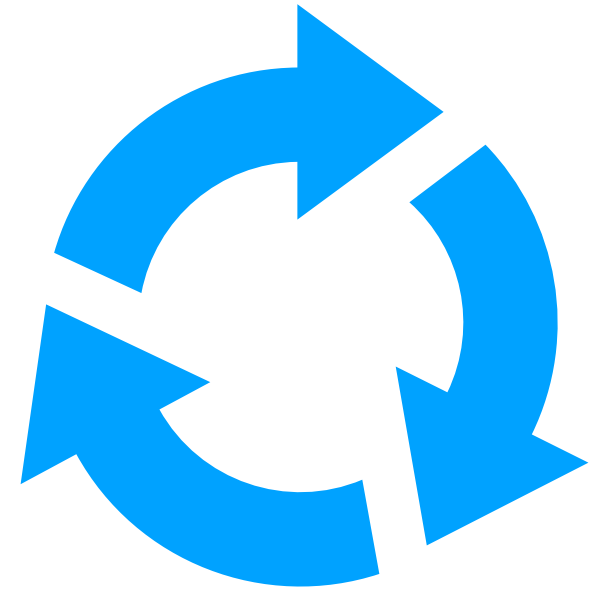
Sewing pattern



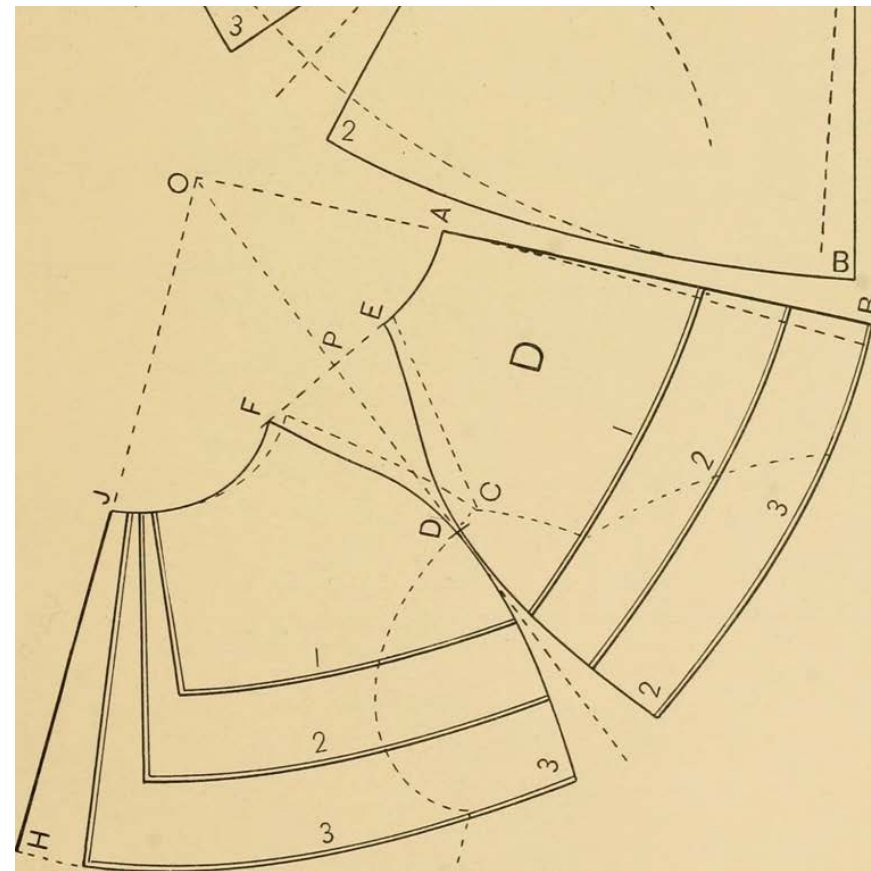
3D shape



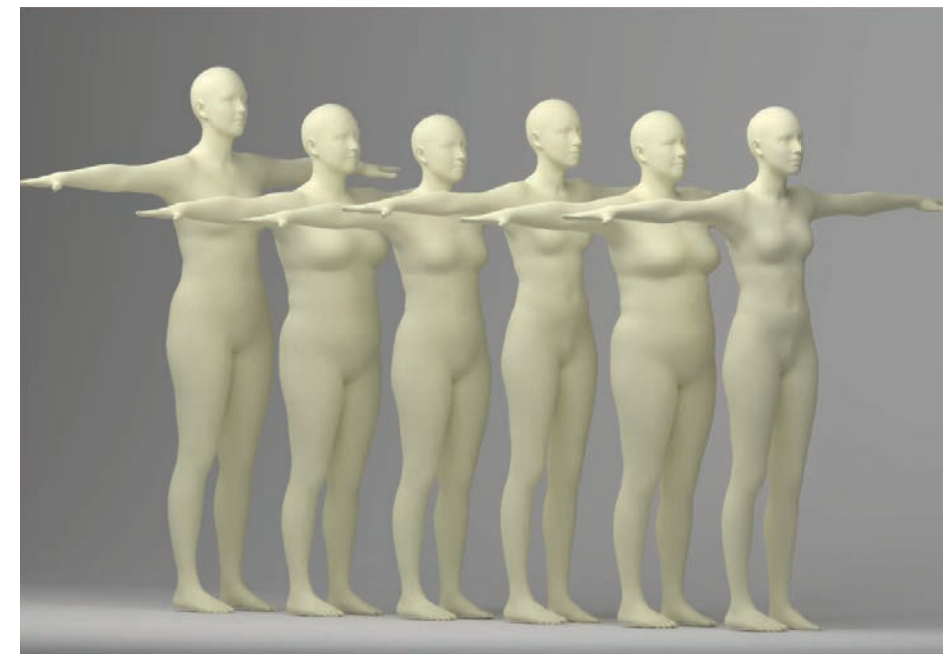
2D Sketch



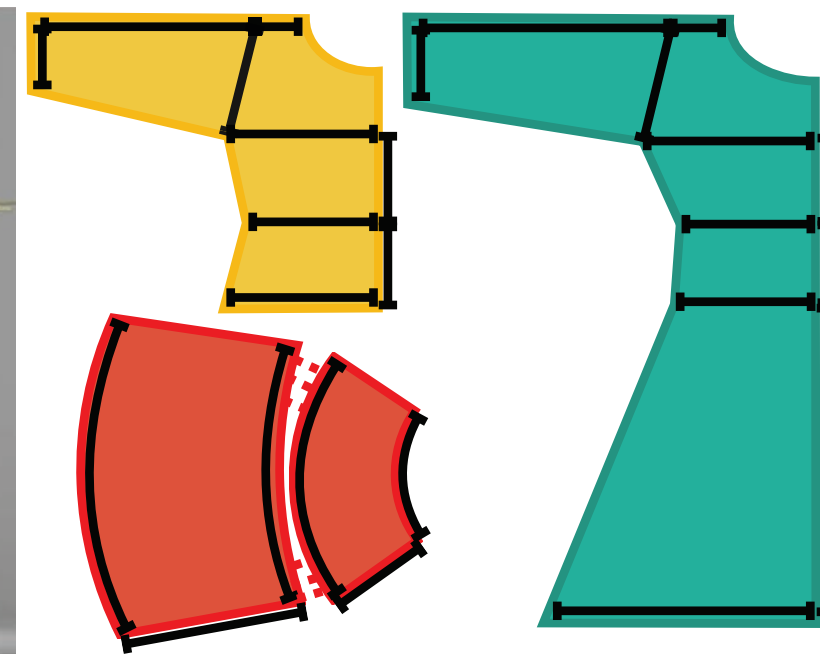
3D shape



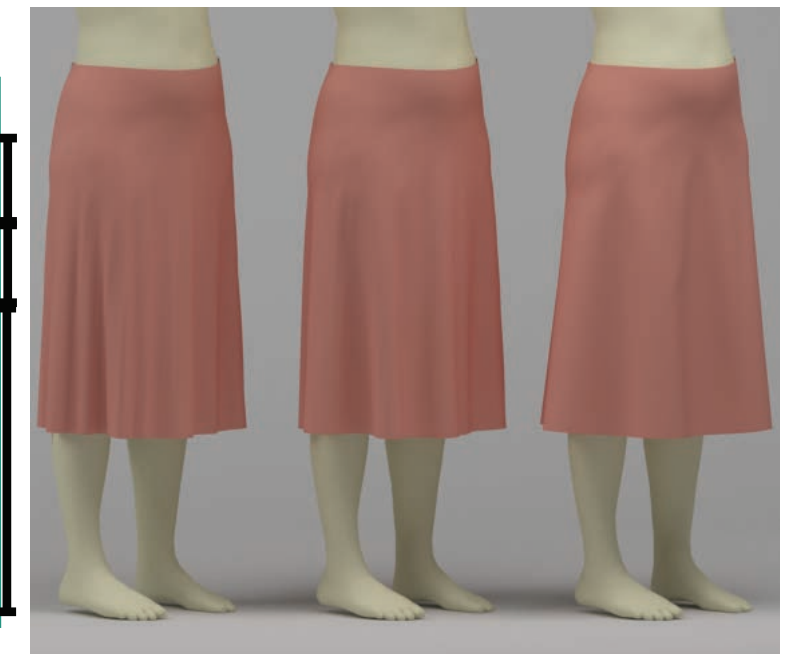
Sewing pattern



SMPL body shapes



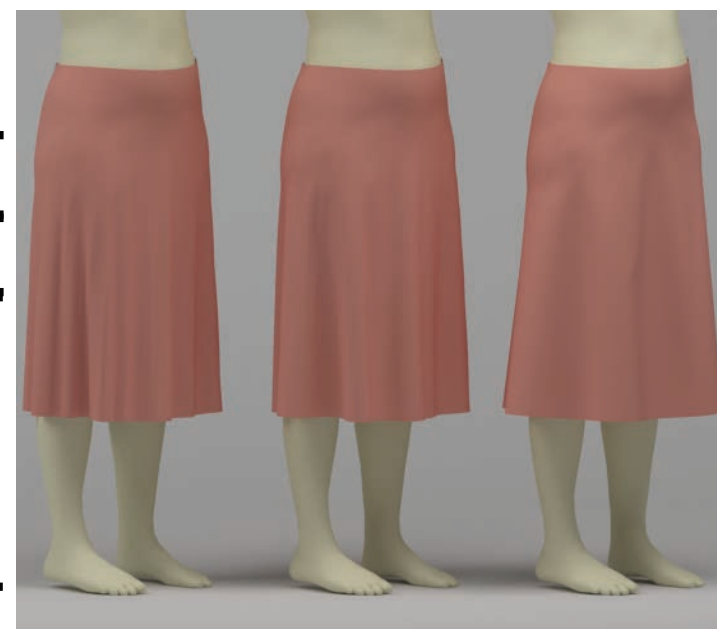
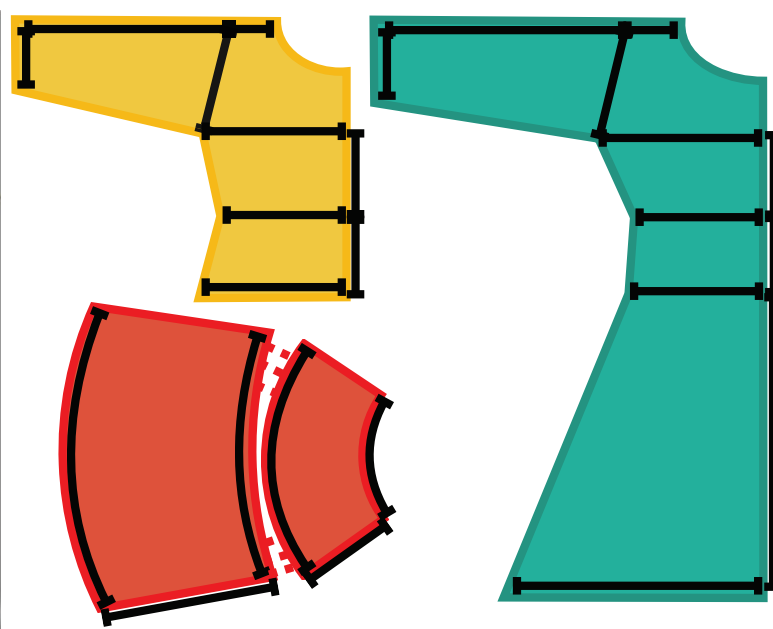
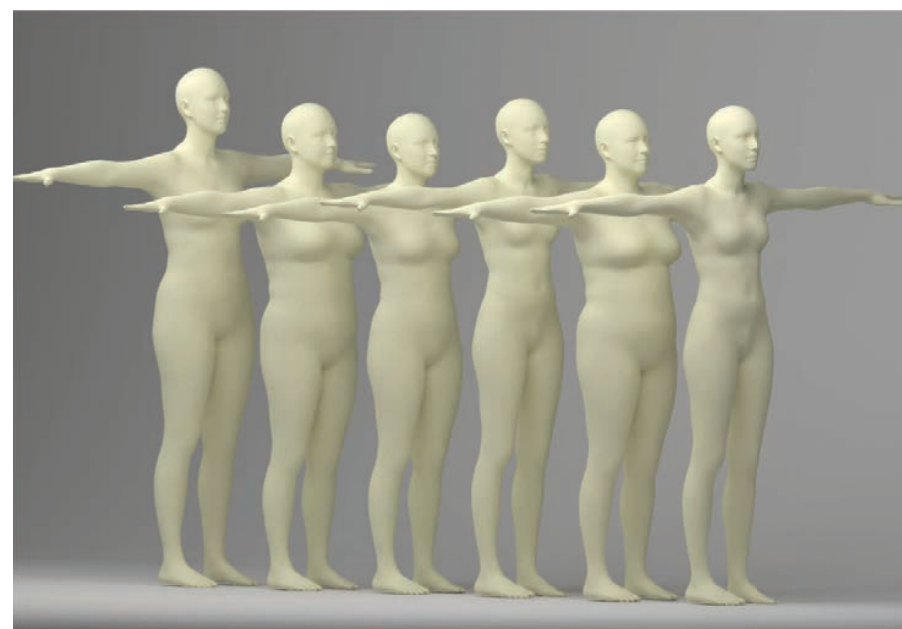
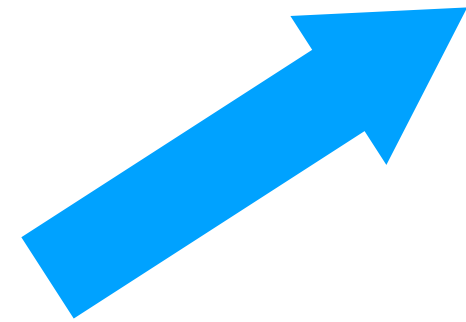
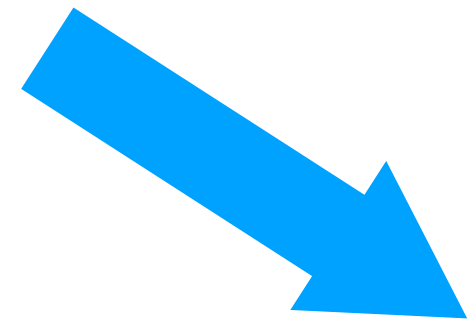
2D sewing patterns



material properties

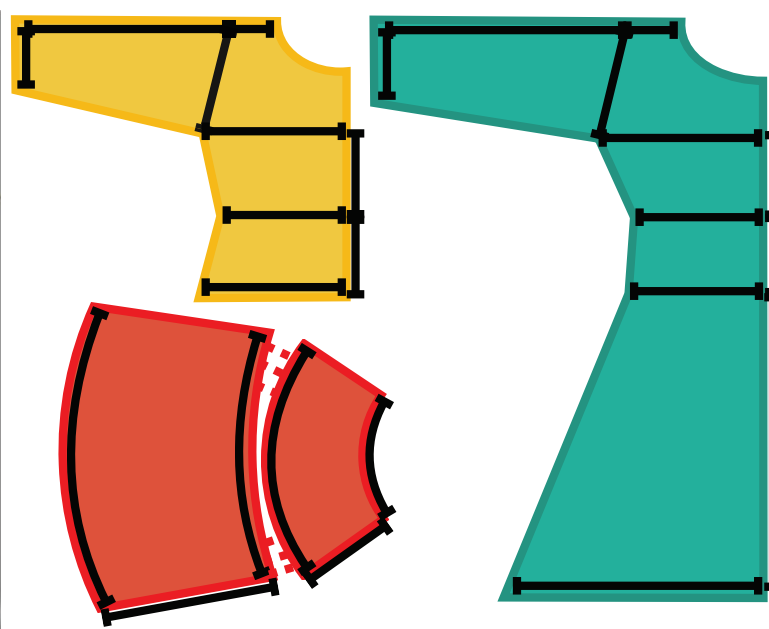
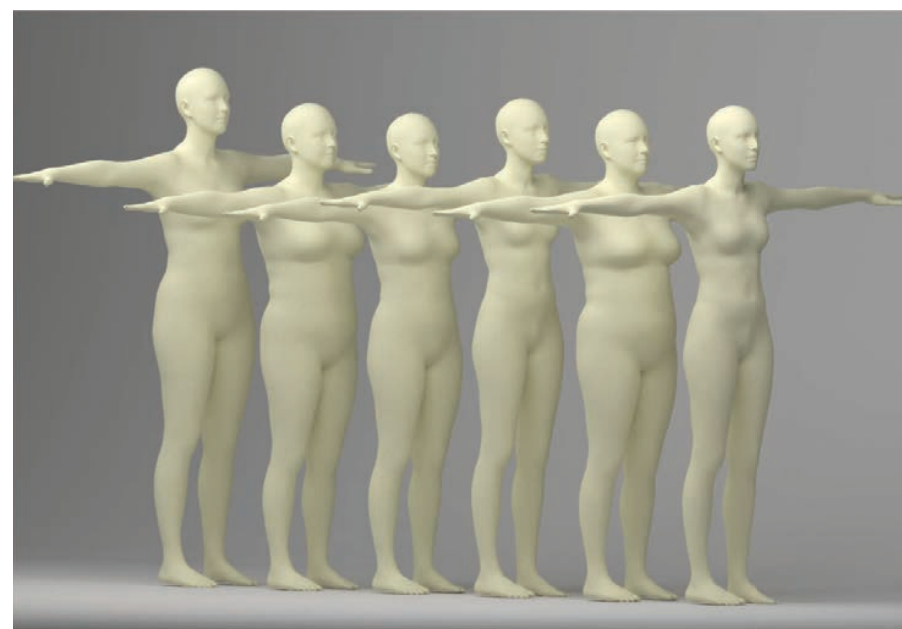
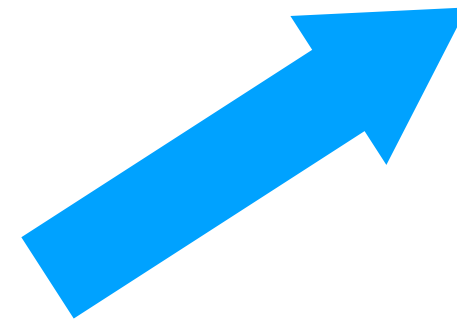
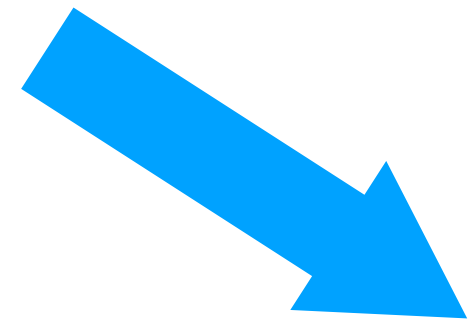


Data Driven



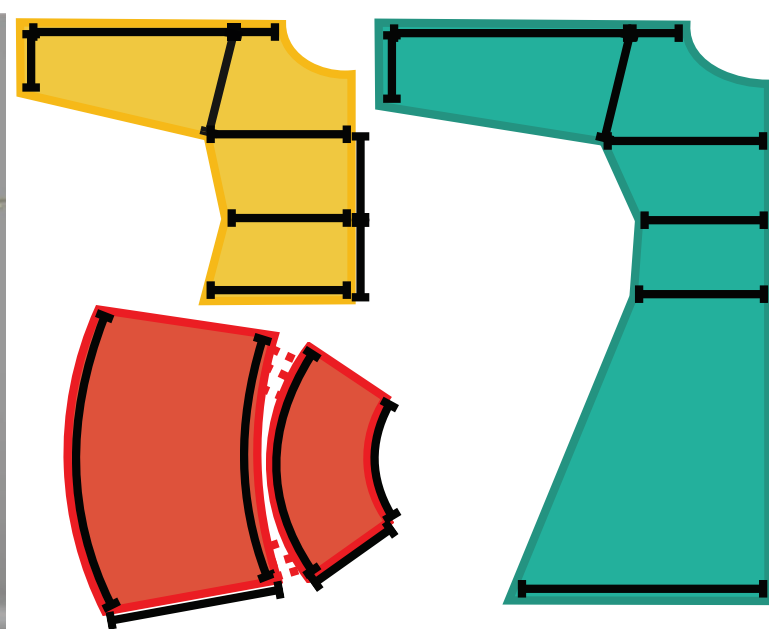
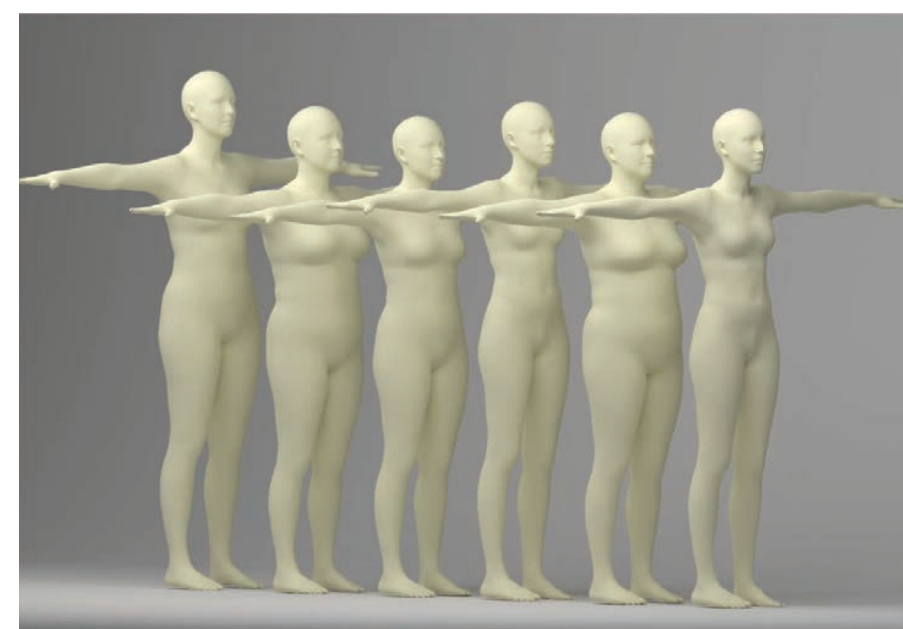
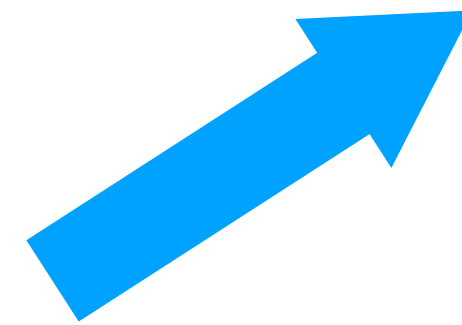
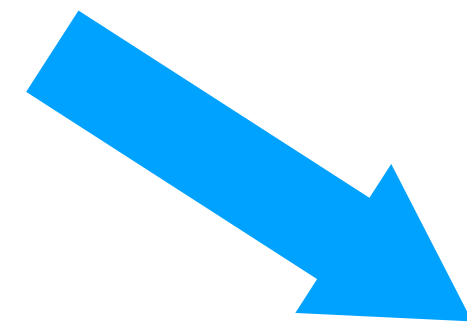


Data Driven



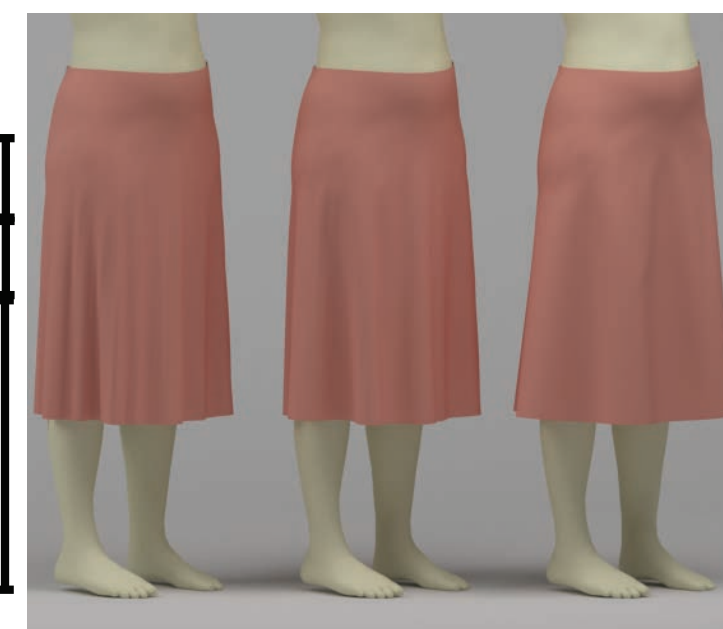
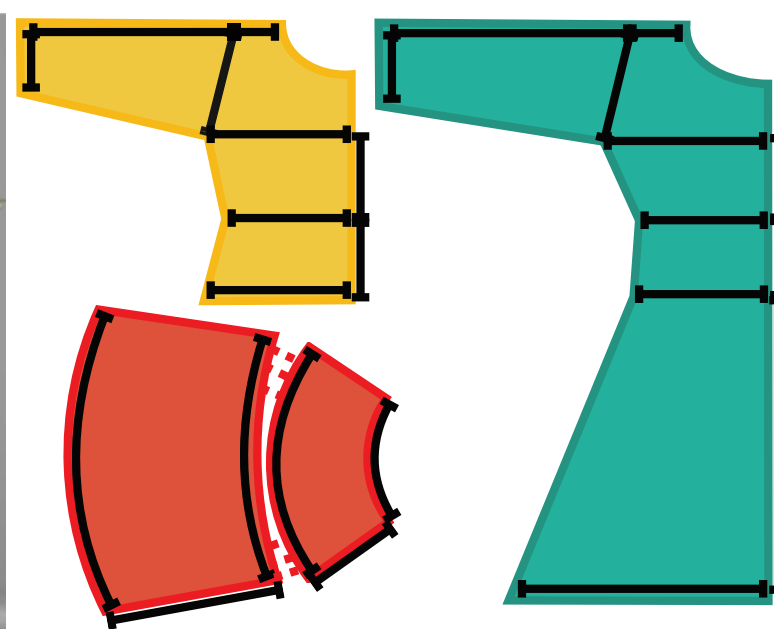
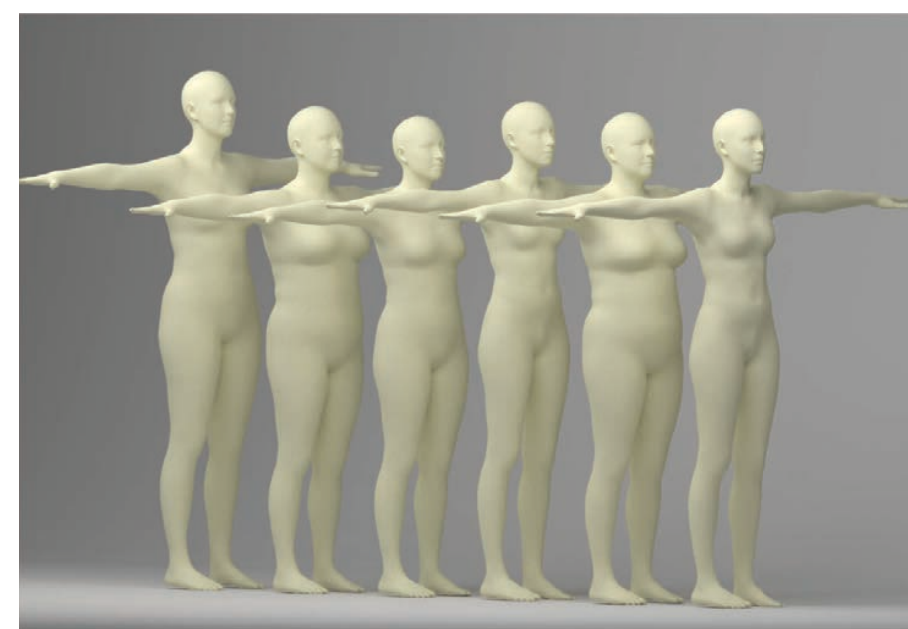
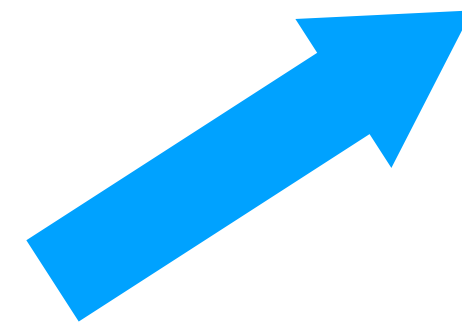
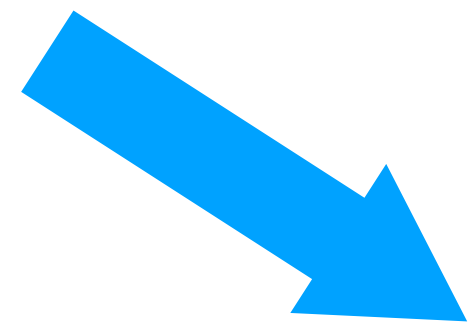


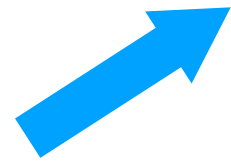
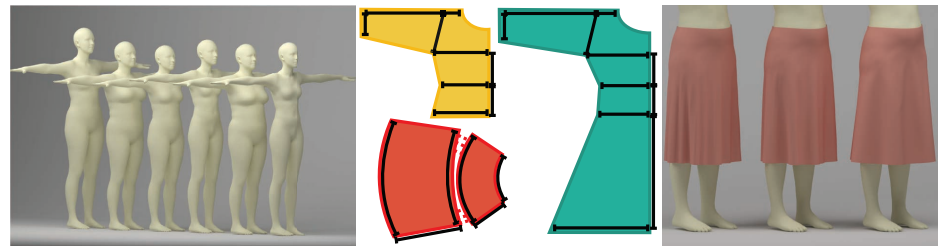
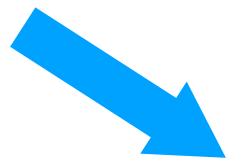
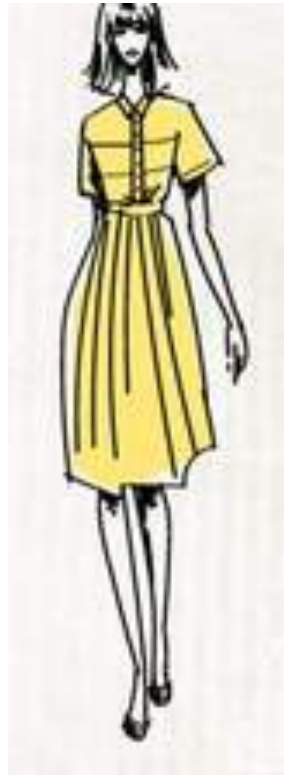
Data Driven

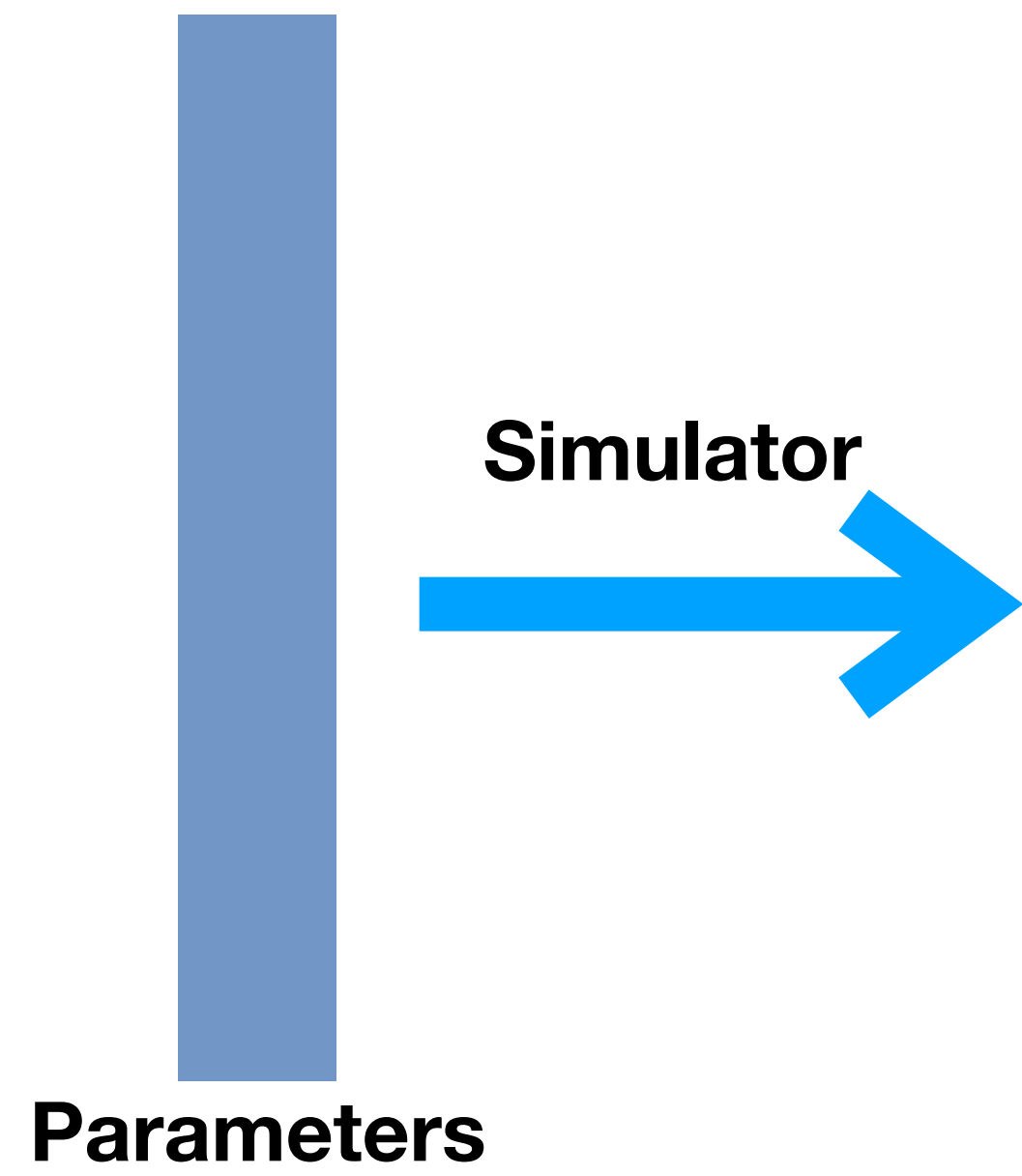
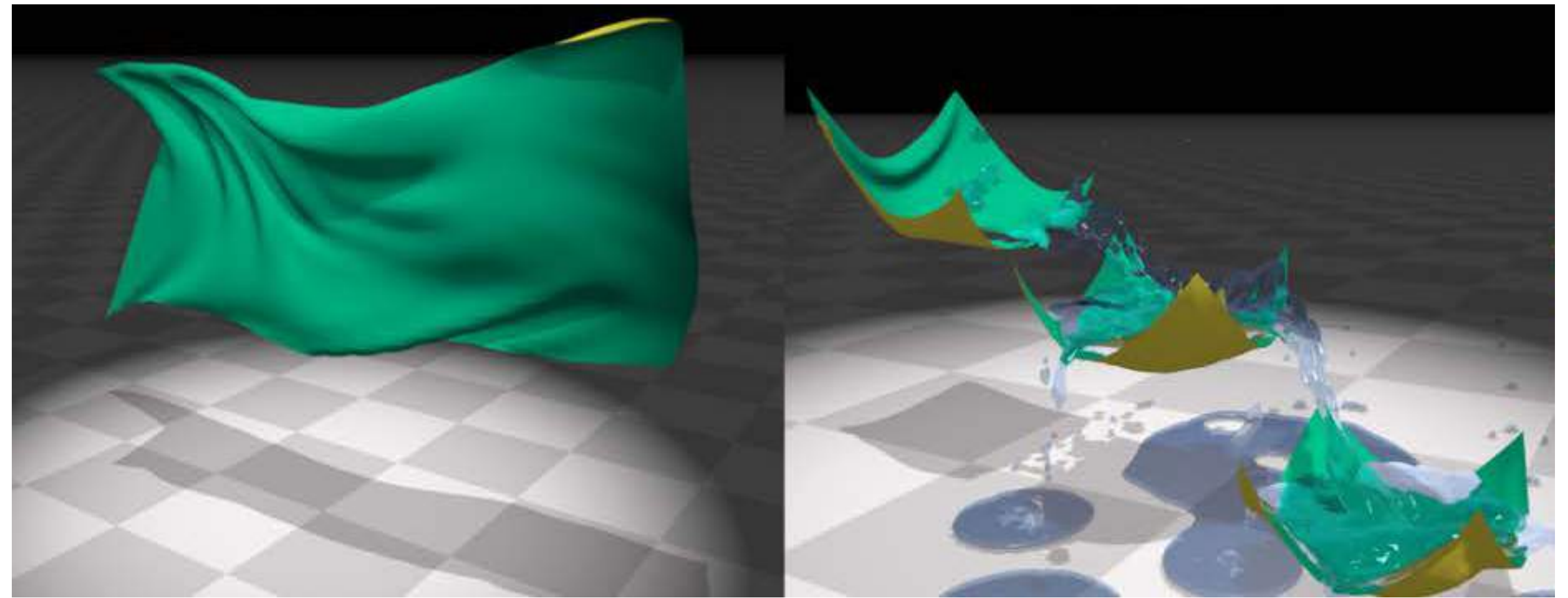
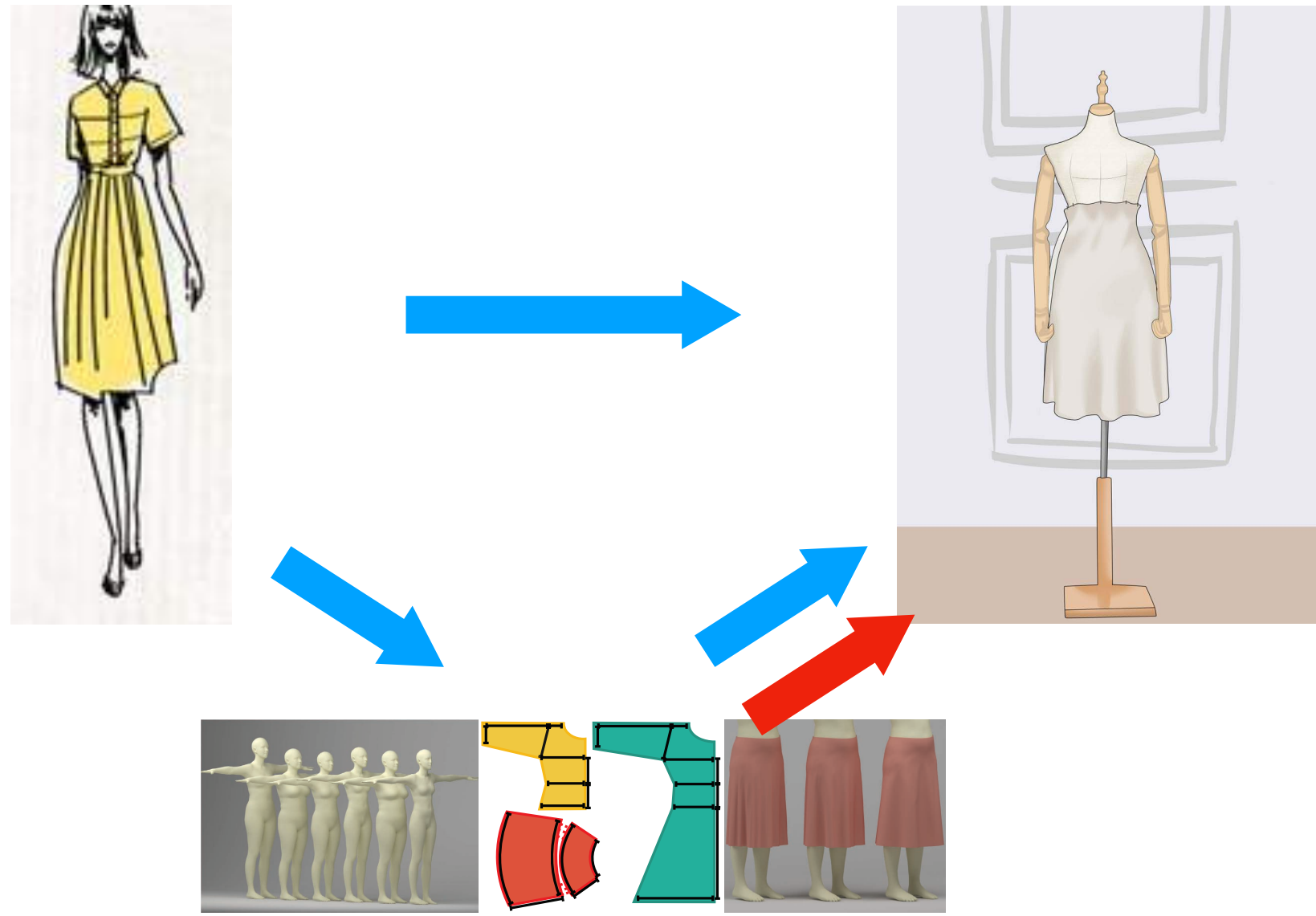


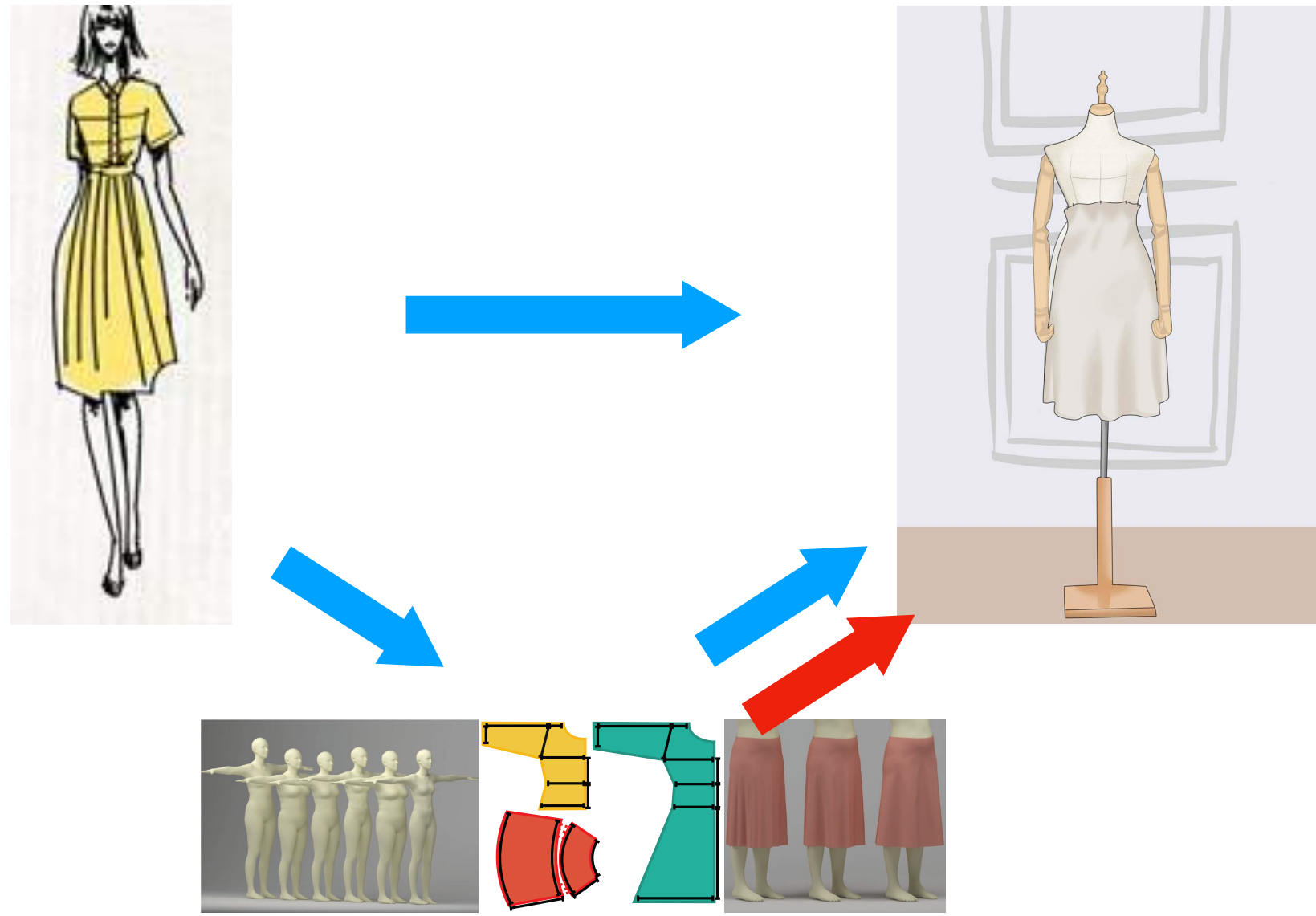


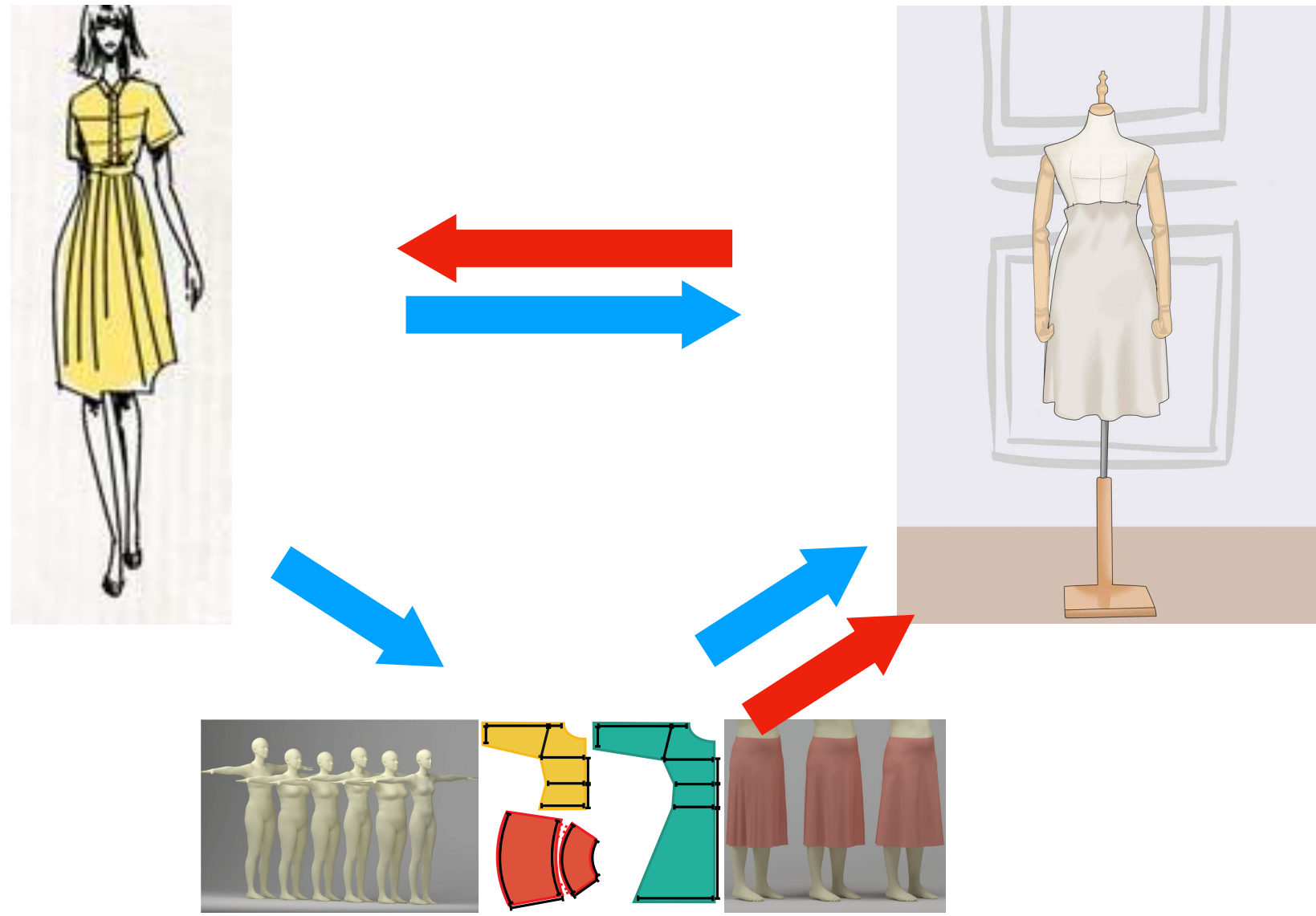
Data Driven







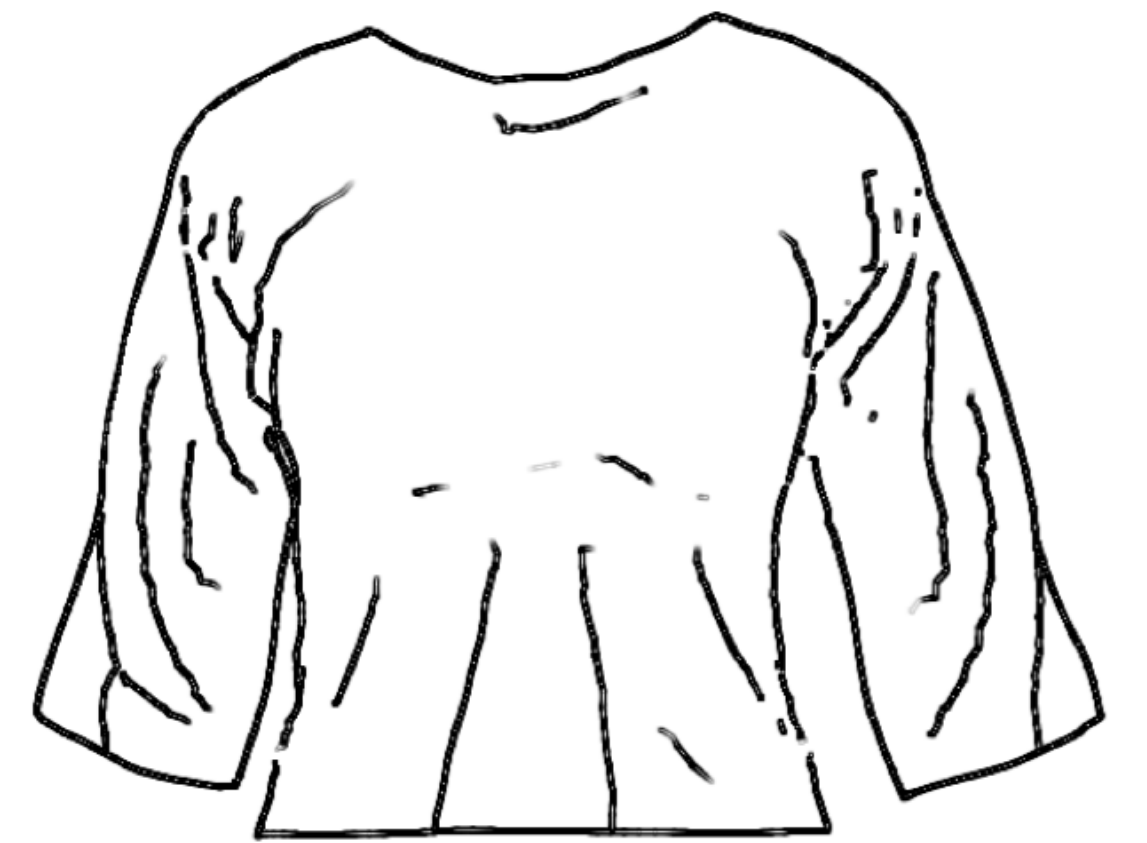


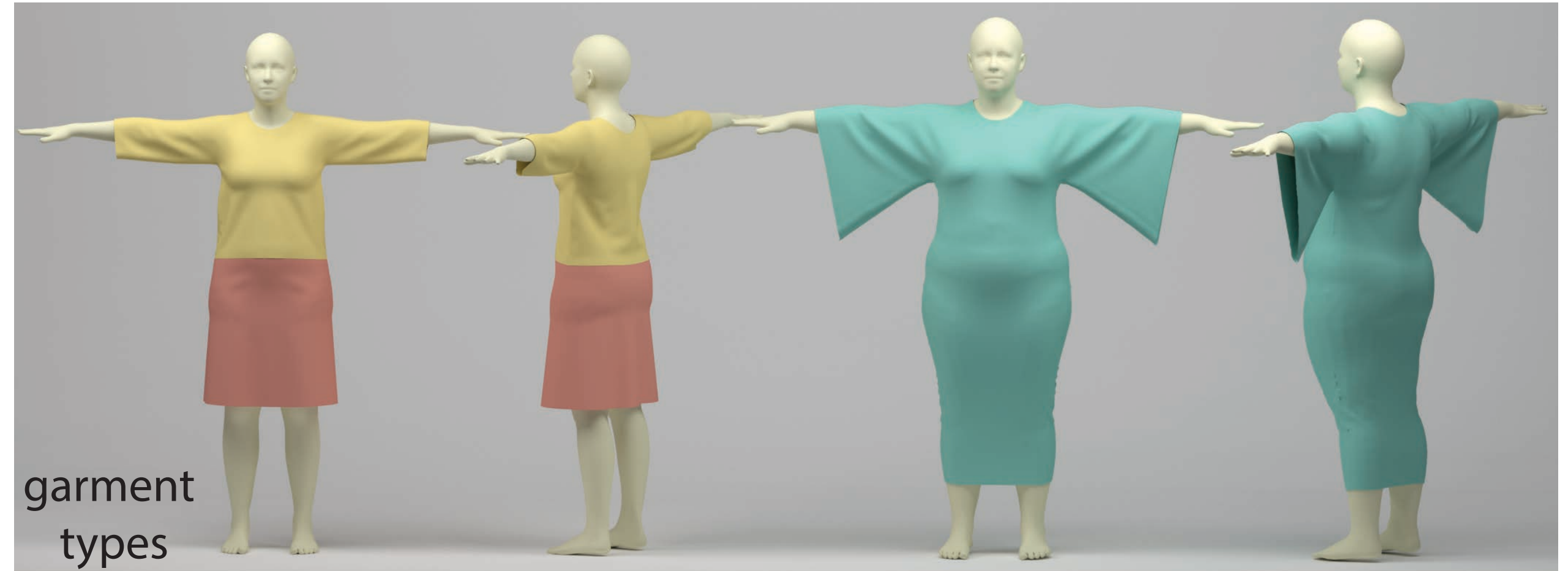
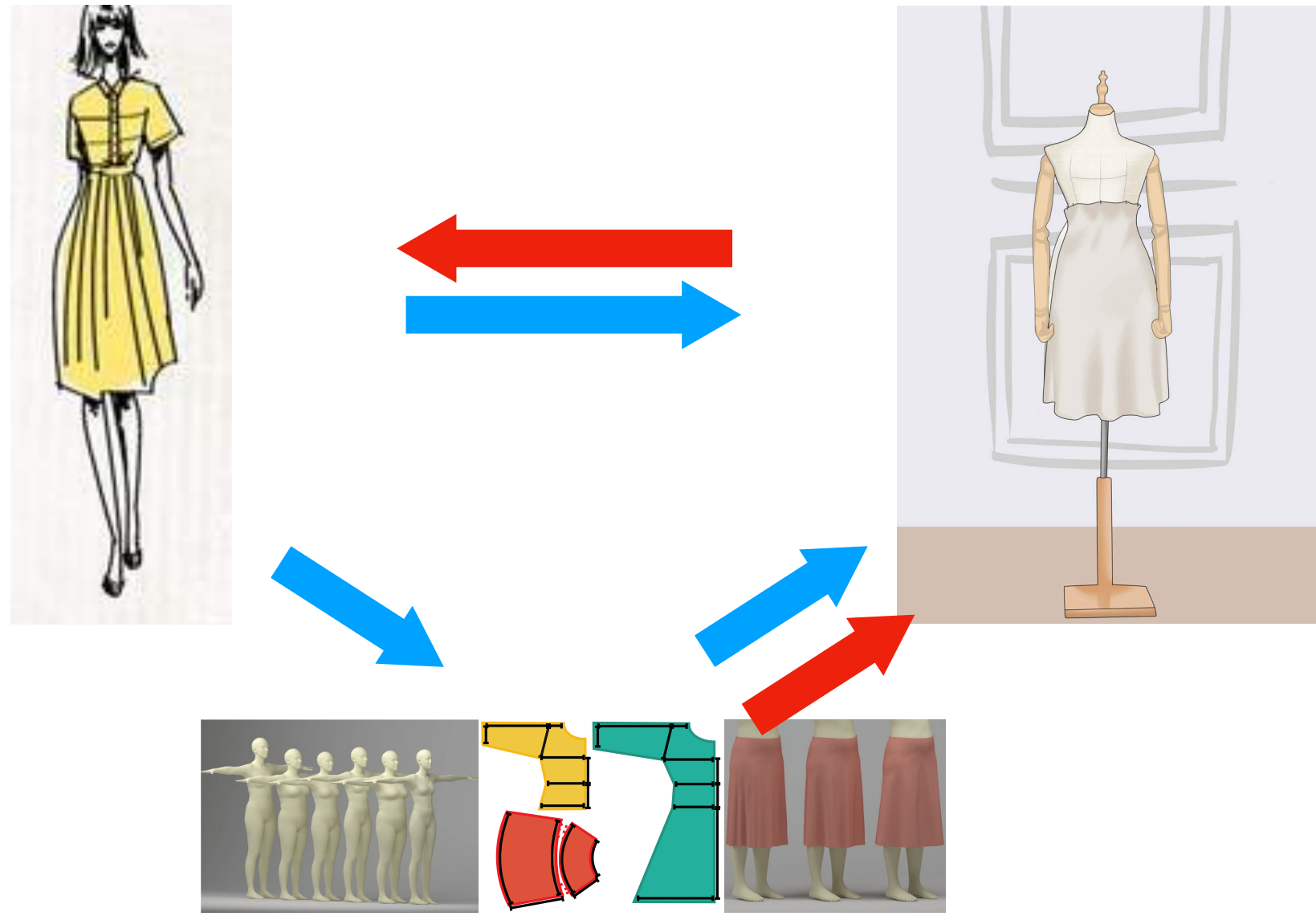


Parameters

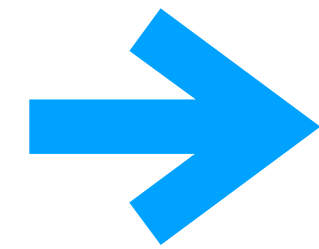


NPR

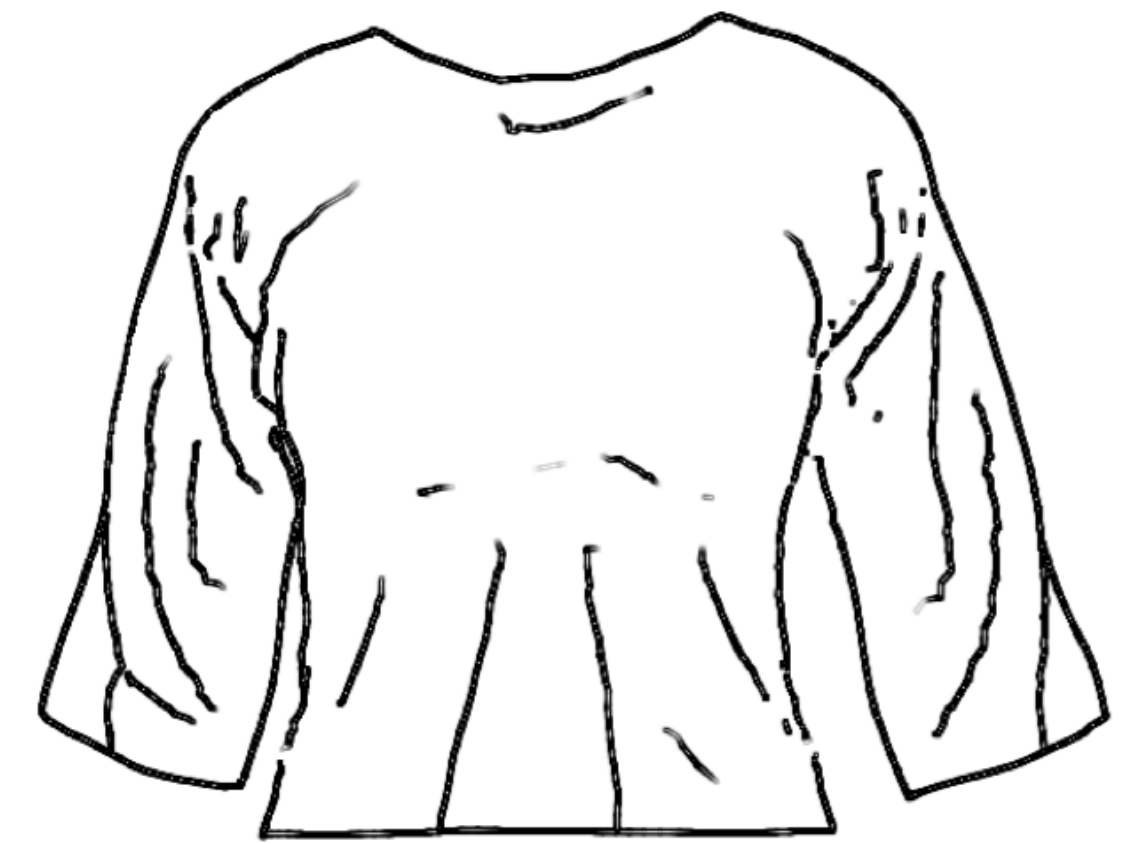
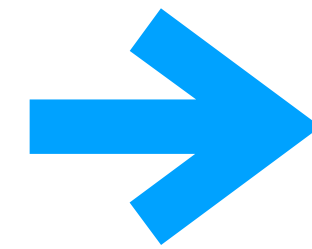


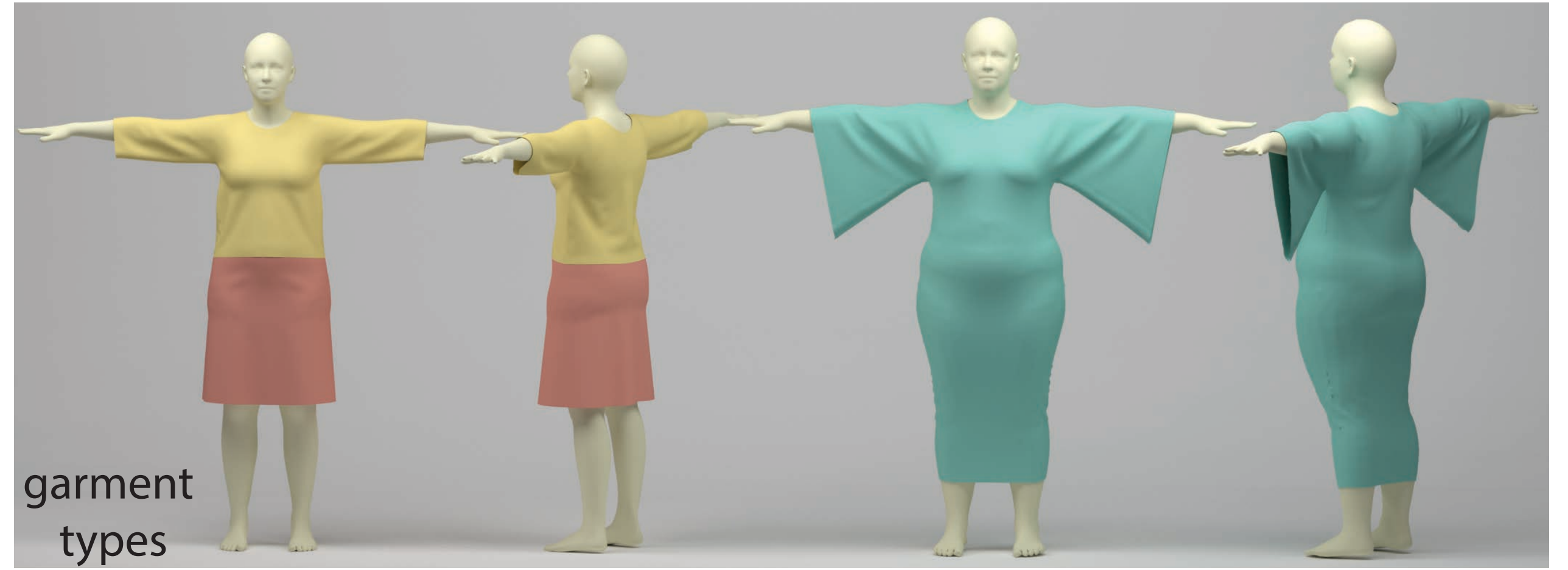
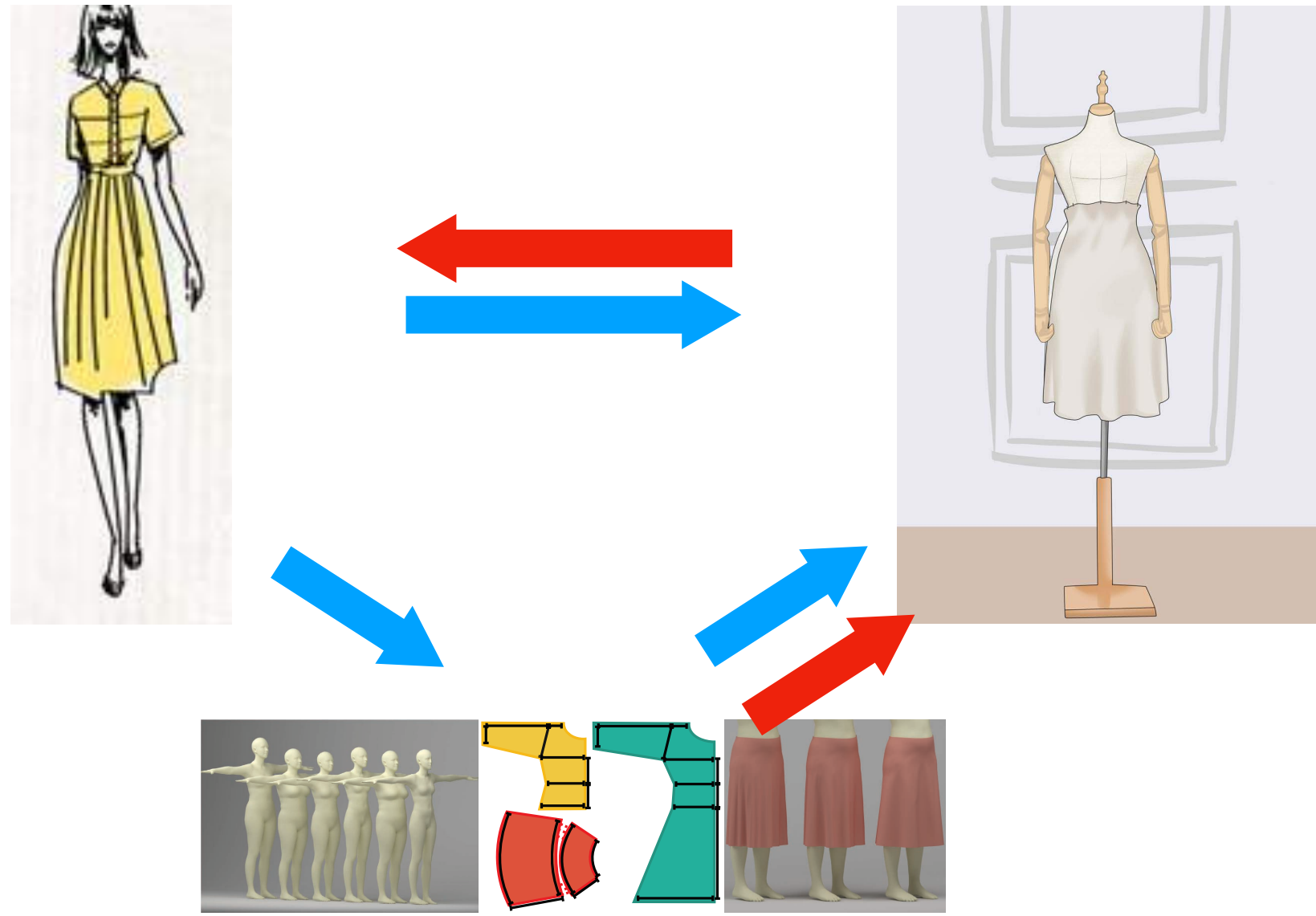


Parameters

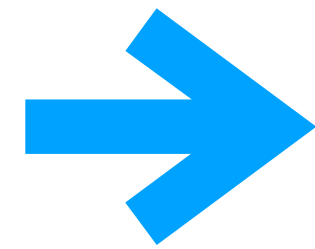


NPR

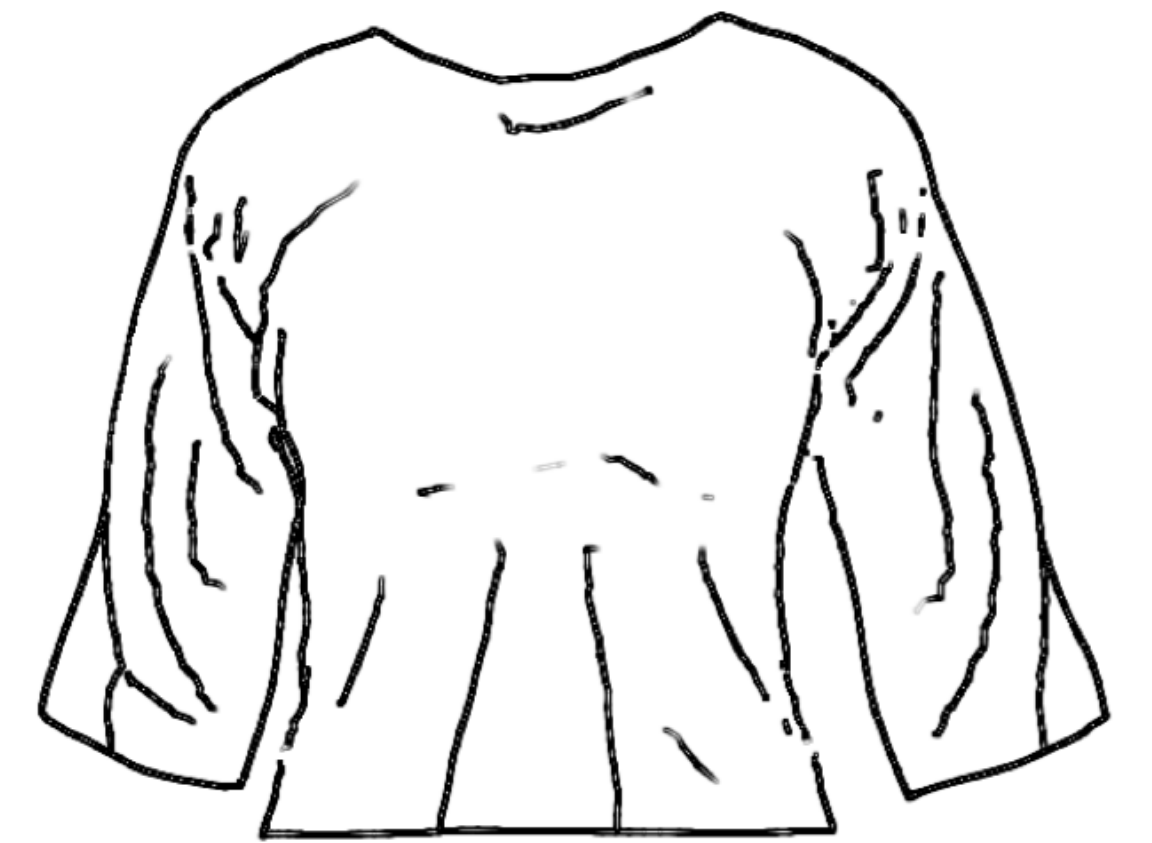
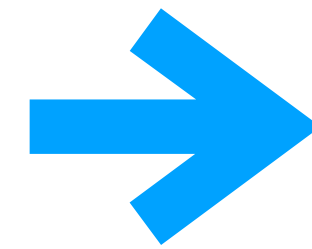


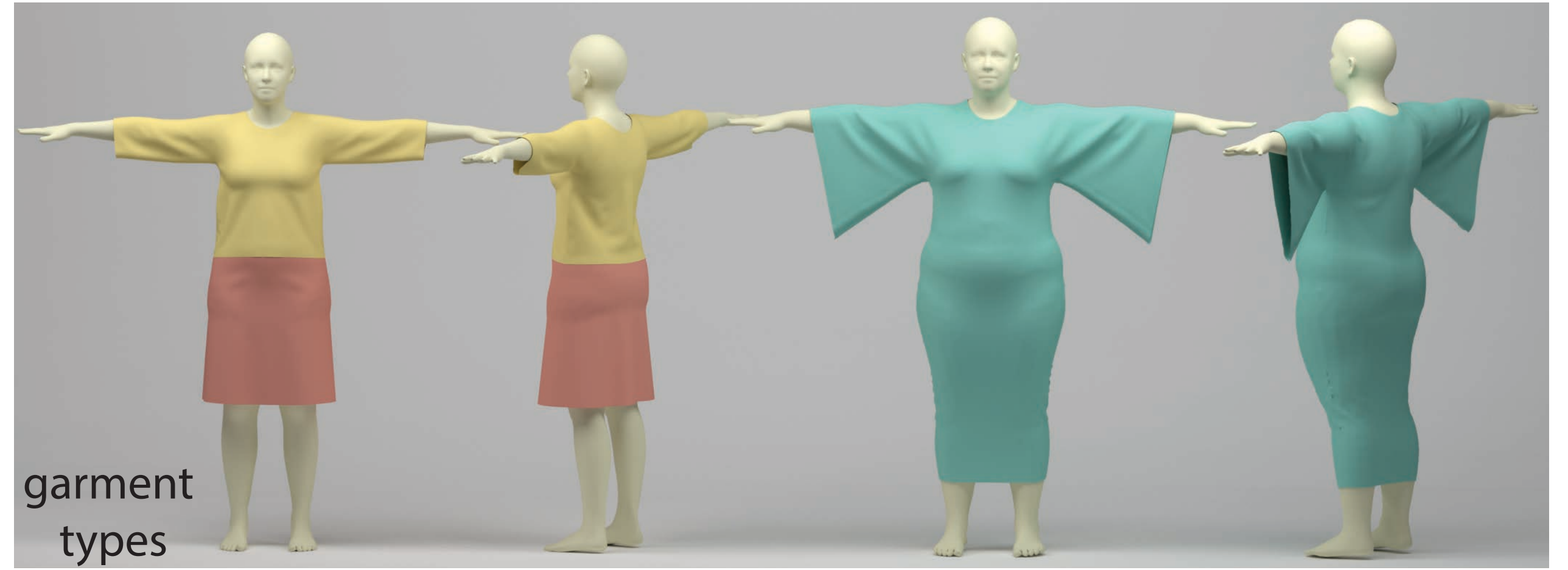
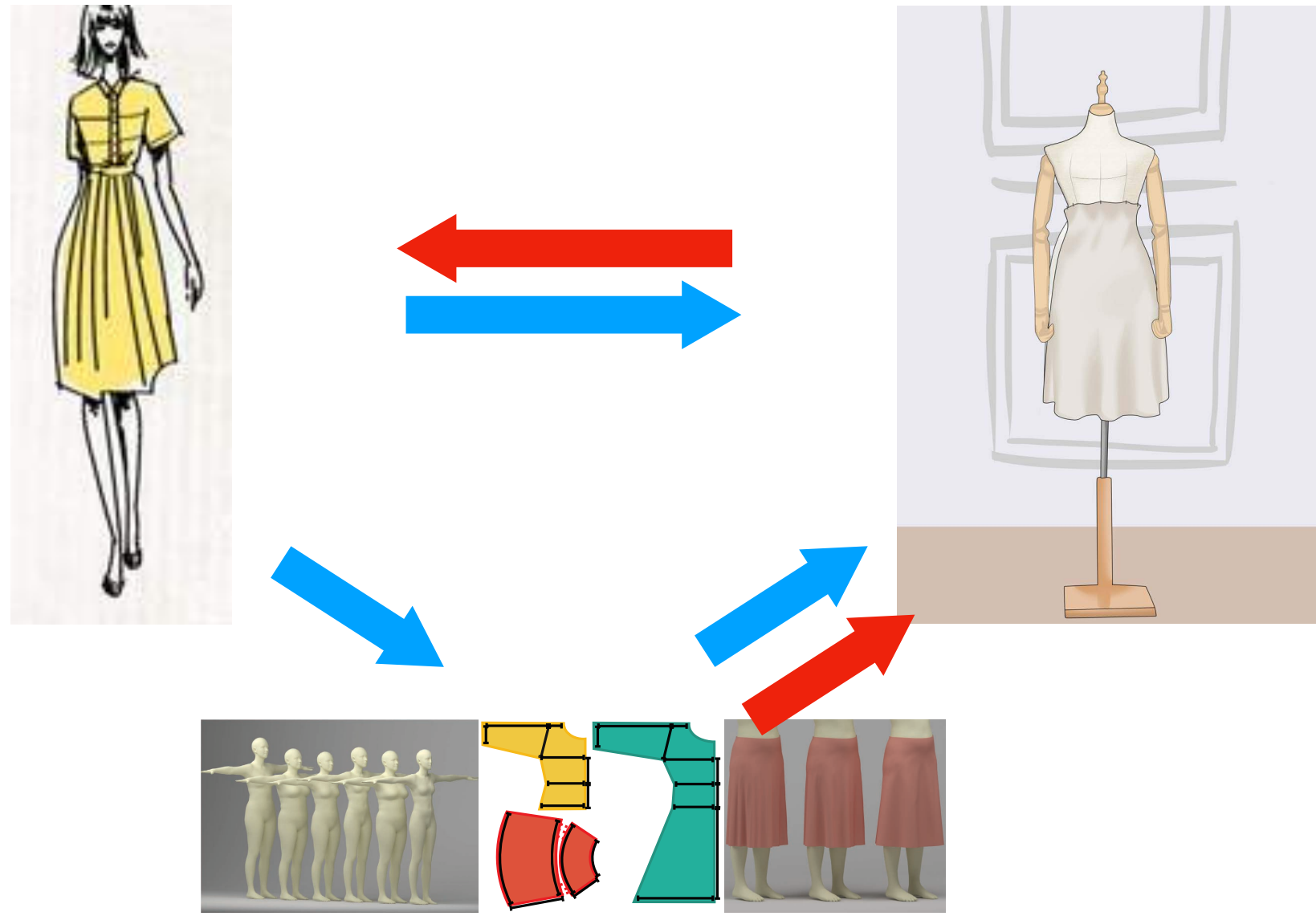


Parameters



NPR

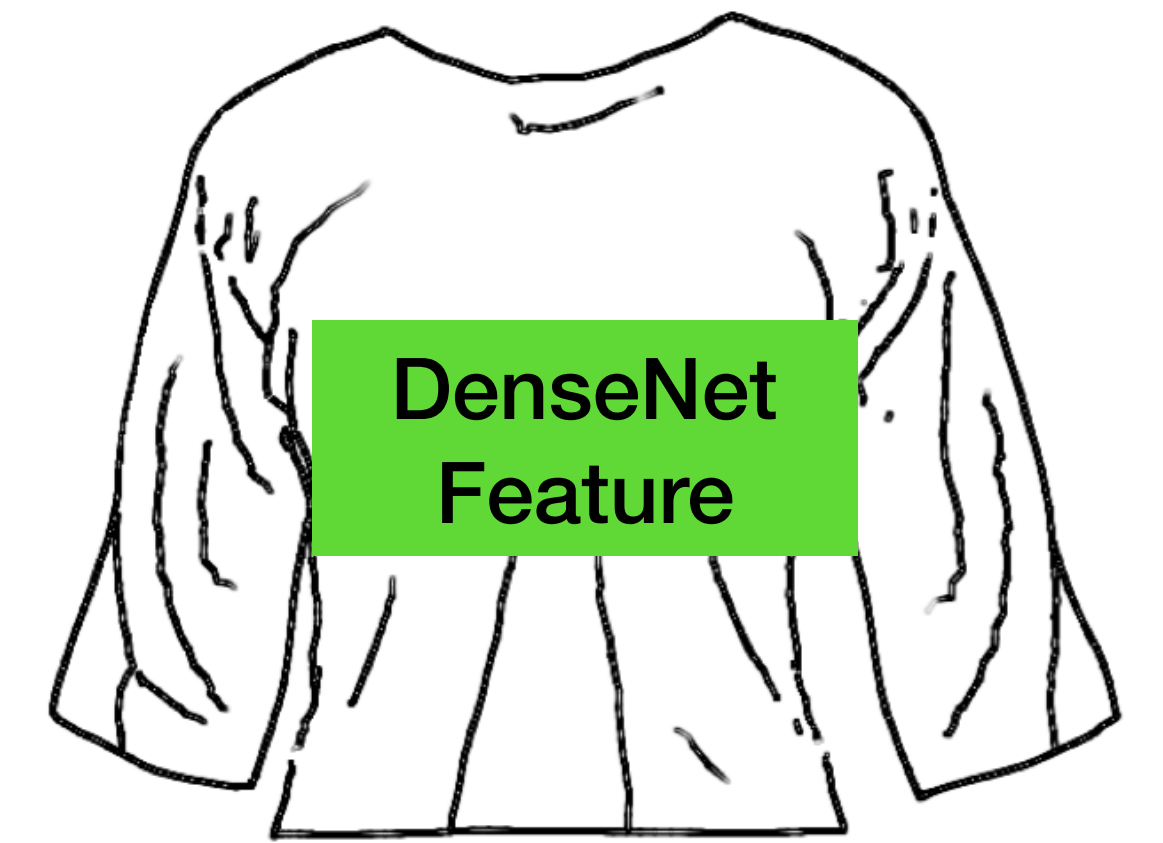




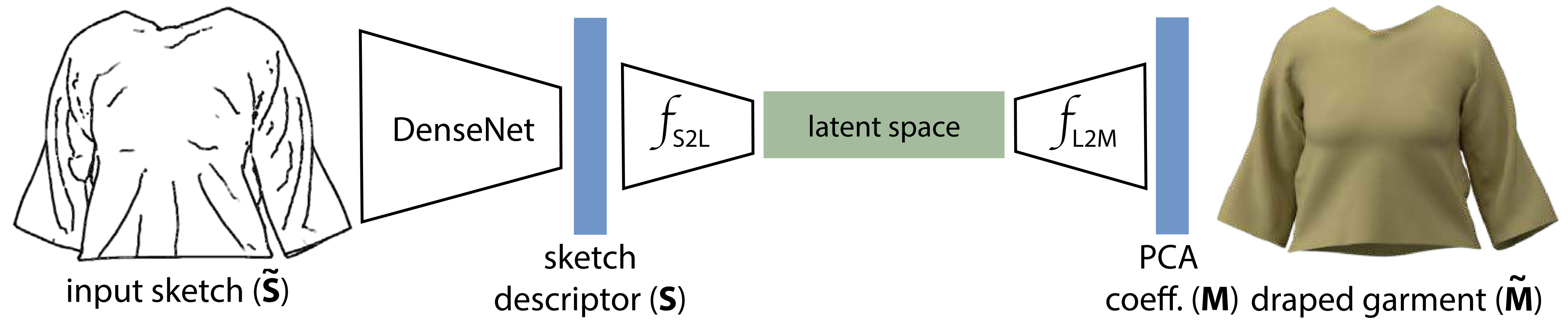
Parameters



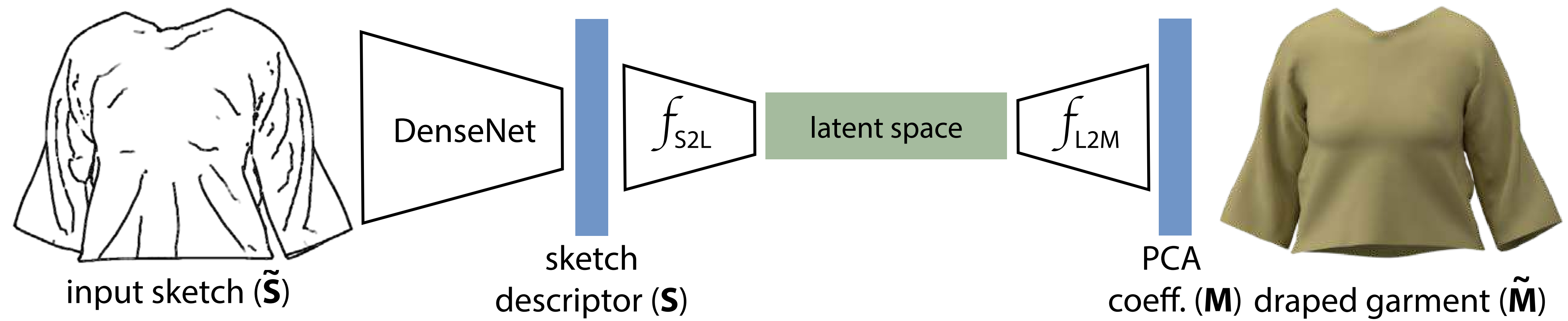
NPR



A naive test..



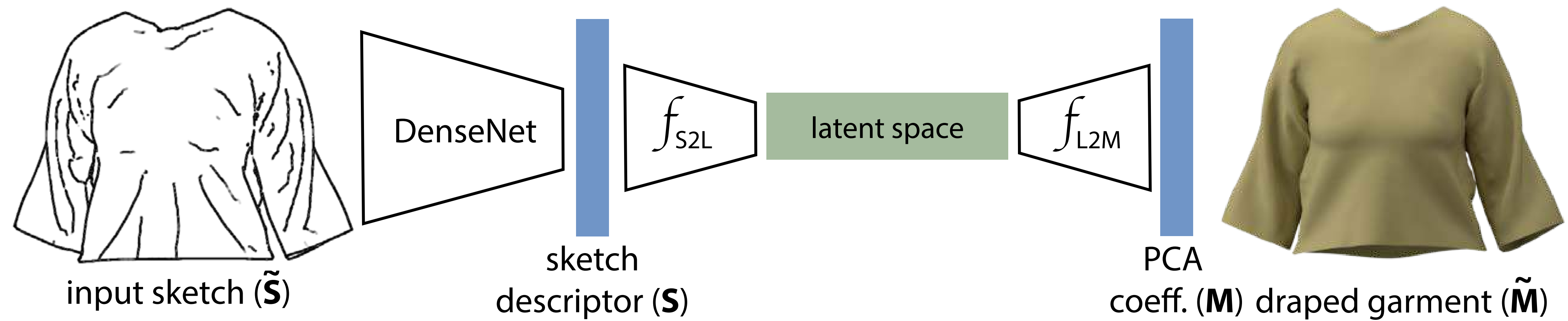
A naive test..



$$\mathcal{L}(\mathbf{P}, \mathbf{M}, \mathbf{S}) =$$

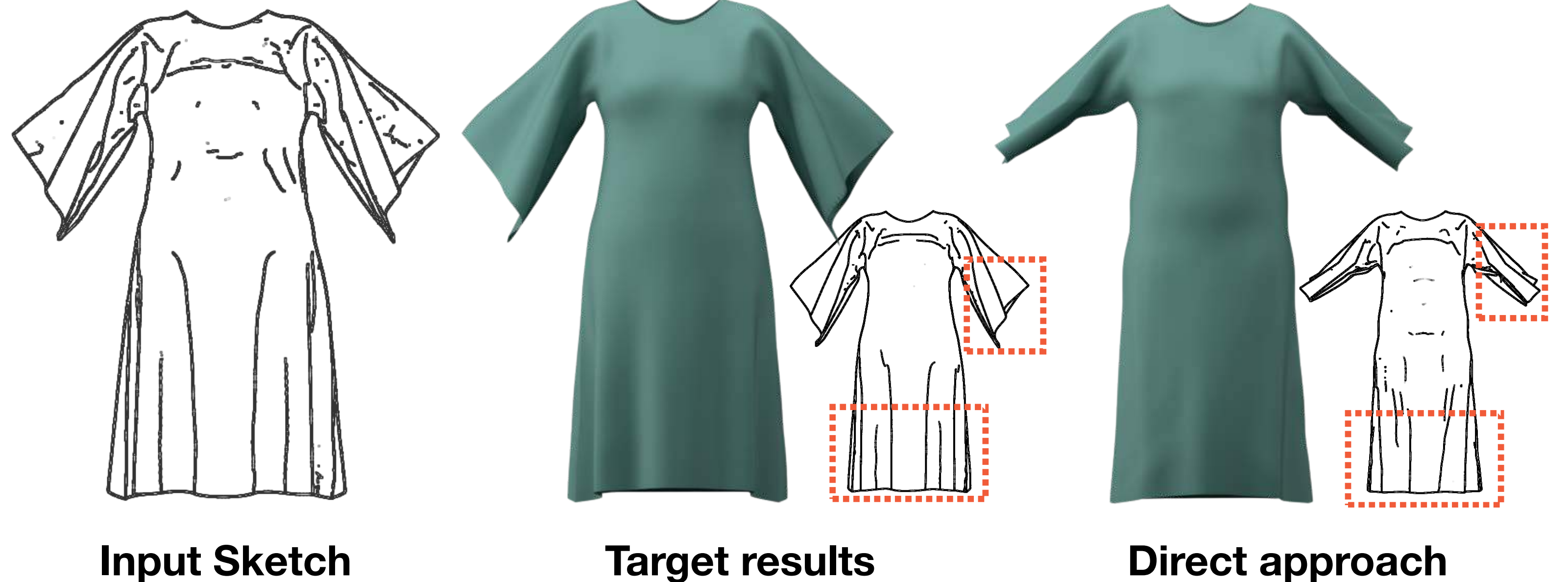
$$\|\mathbf{M} - f_{L2M}(f_{S2L}(\mathbf{S}))\|_2$$

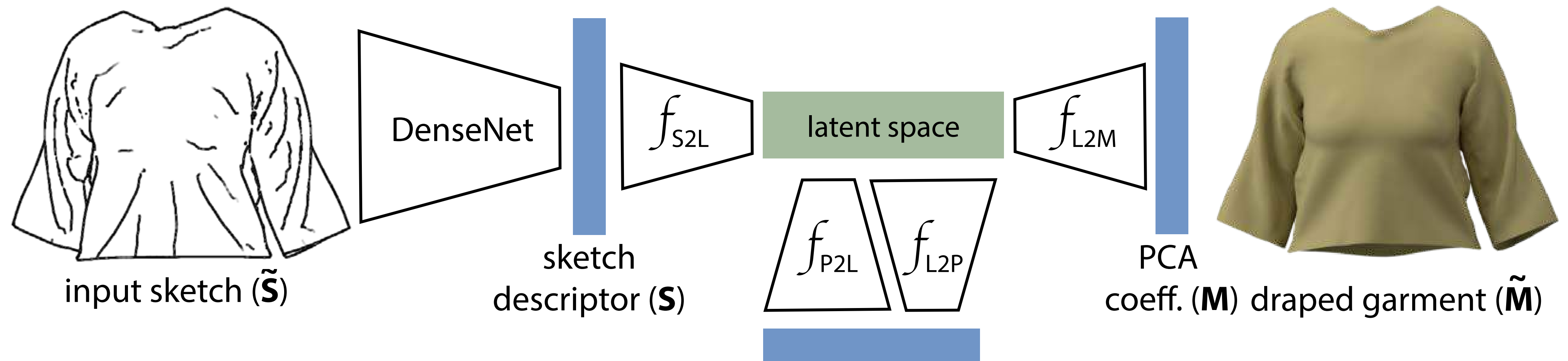
A naive test..



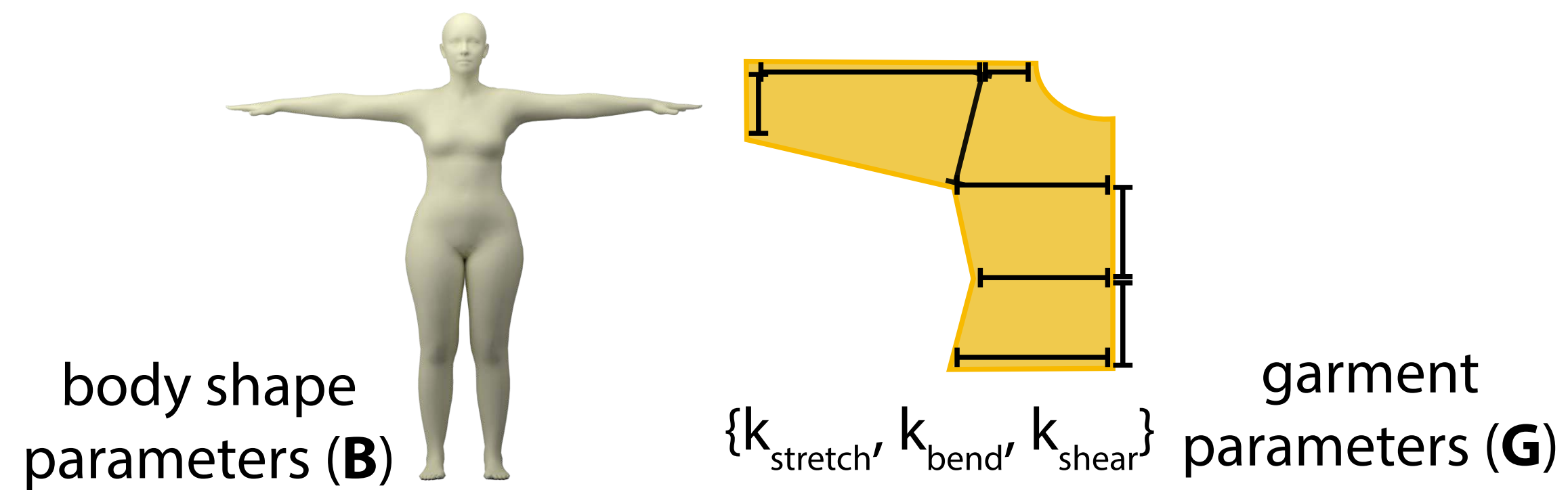
$$\mathcal{L}(P, M, S) =$$

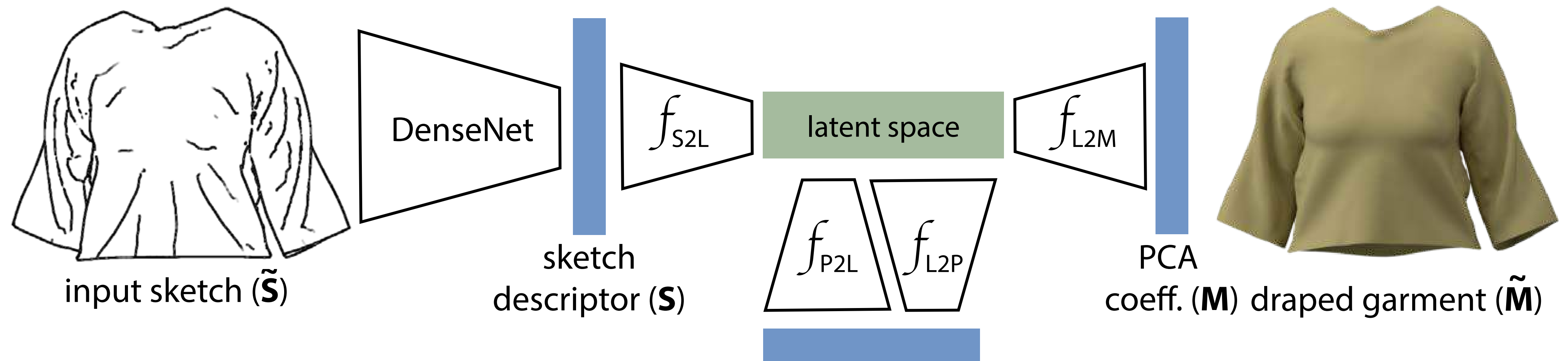
$$\|M - f_{L2M}(f_{S2L}(S))\|_2$$



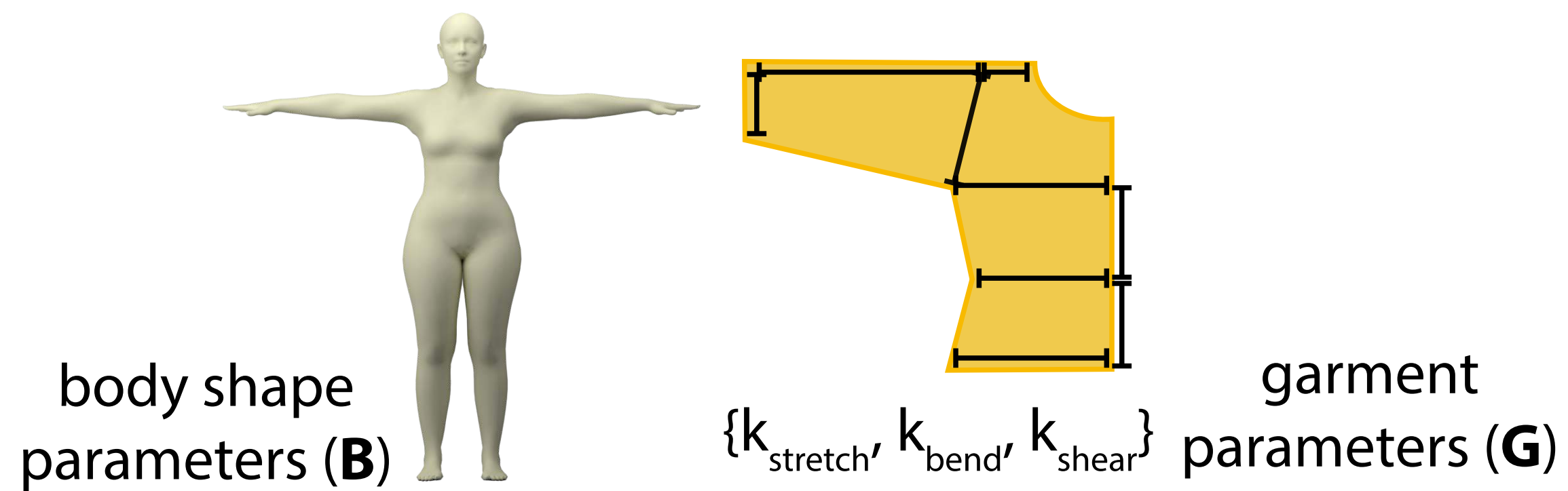


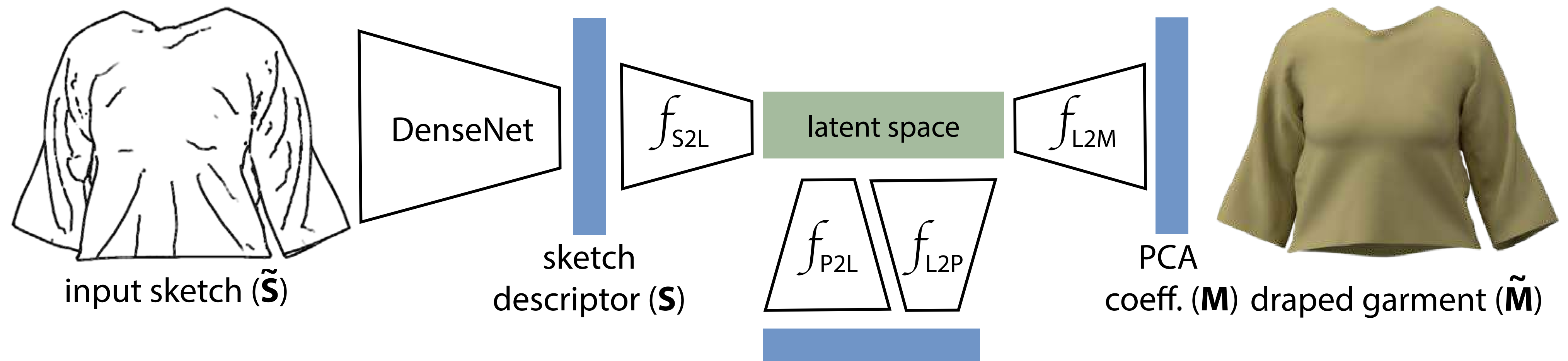
Details Refer to paper



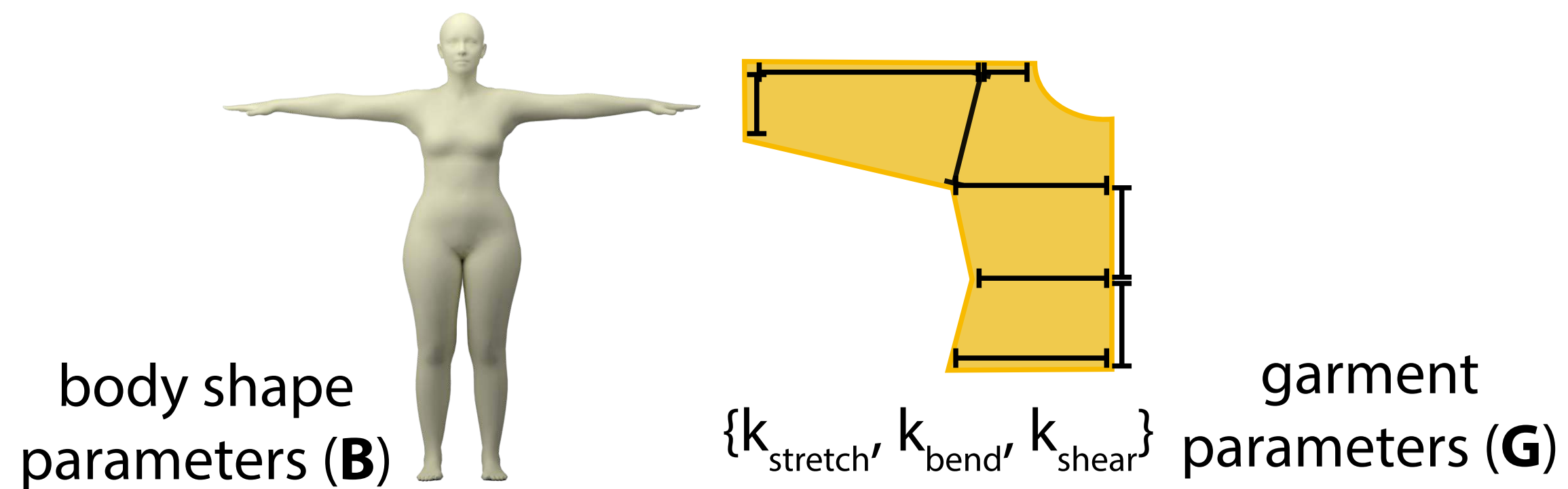


Details Refer to paper

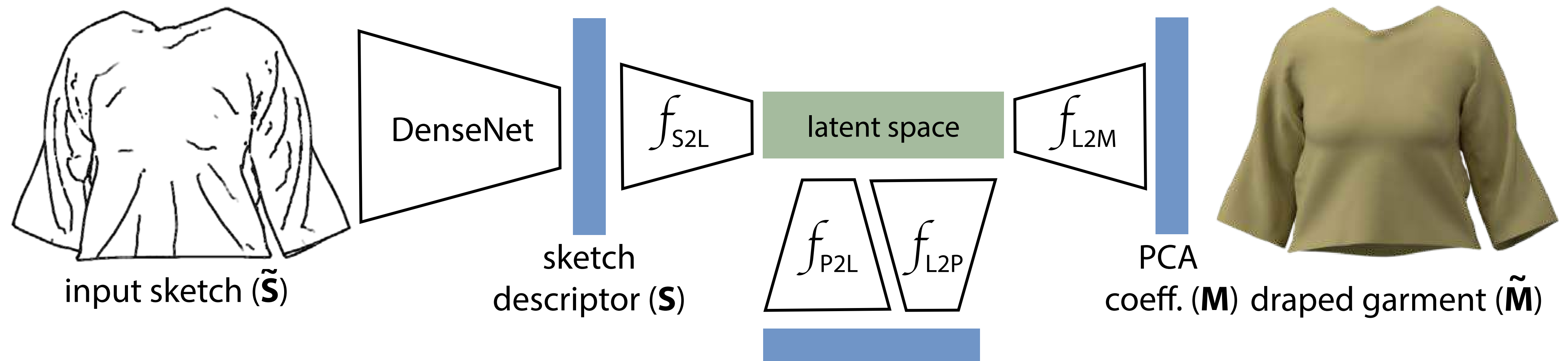




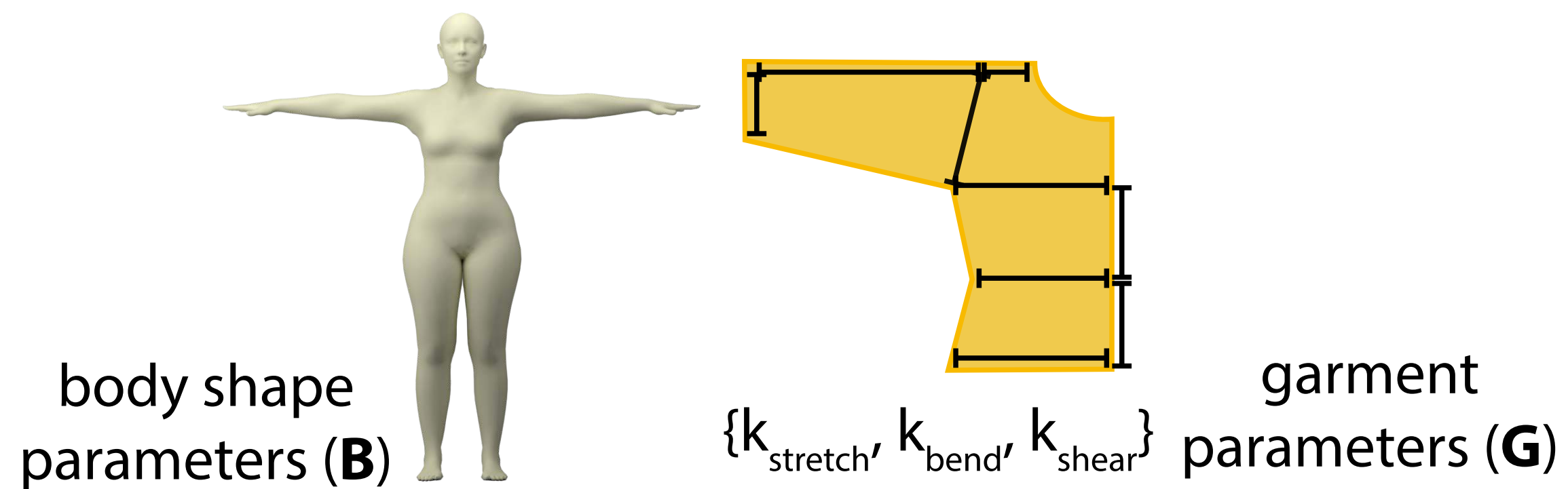
Details Refer to paper



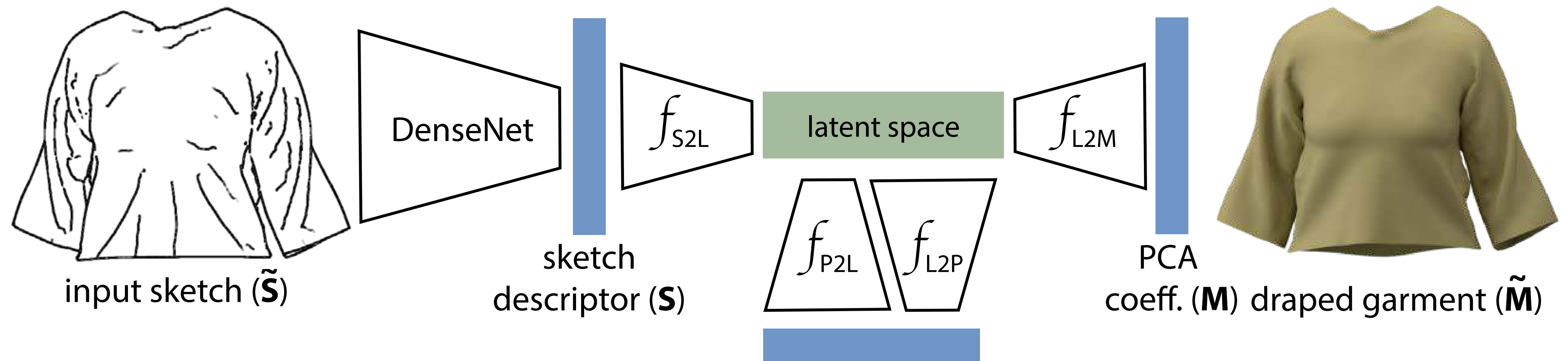
$$\|M - f_{L2M}(f_{S2L}(S))\|_2$$



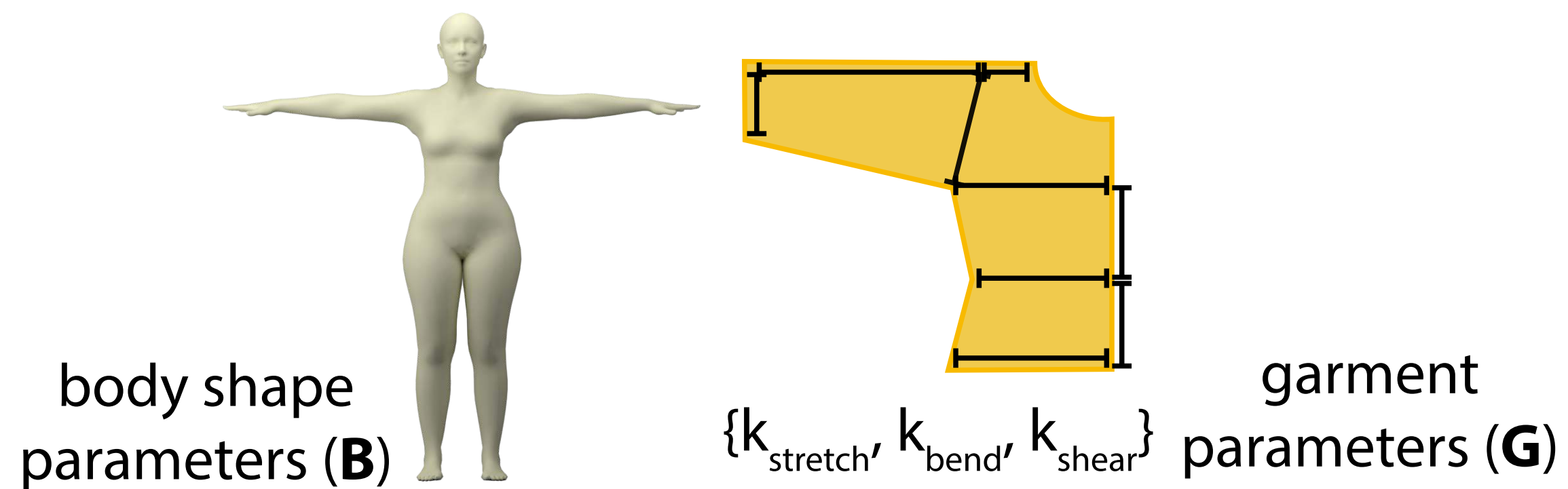
Details Refer to paper



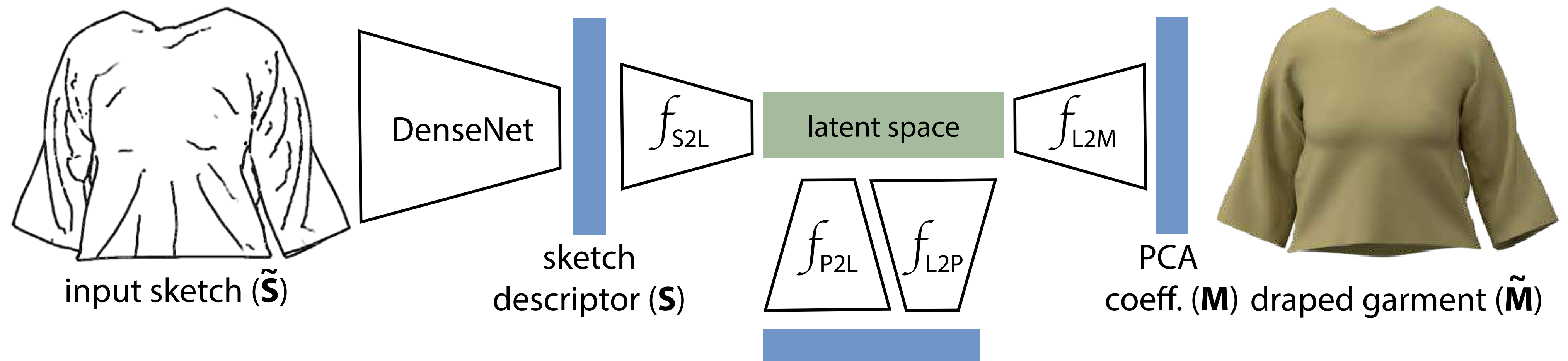
$$\|M - f_{L2M}(f_{S2L}(S))\|_2 \quad \|P - f_{L2P}(f_{S2L}(S))\|_2$$



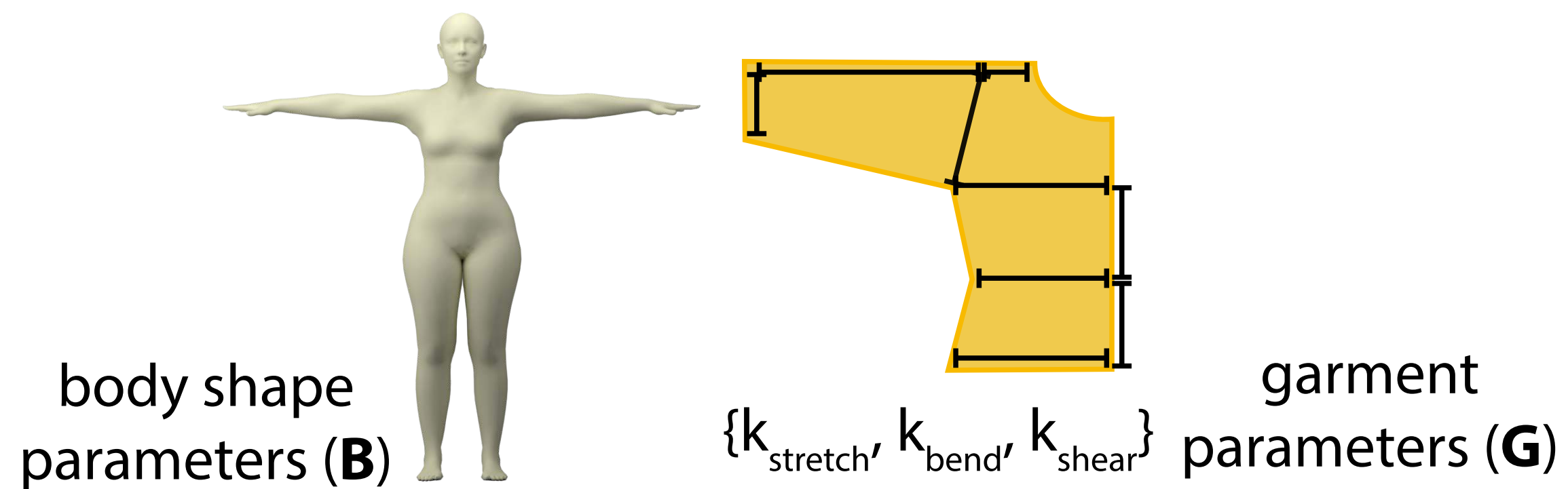
Details Refer to paper



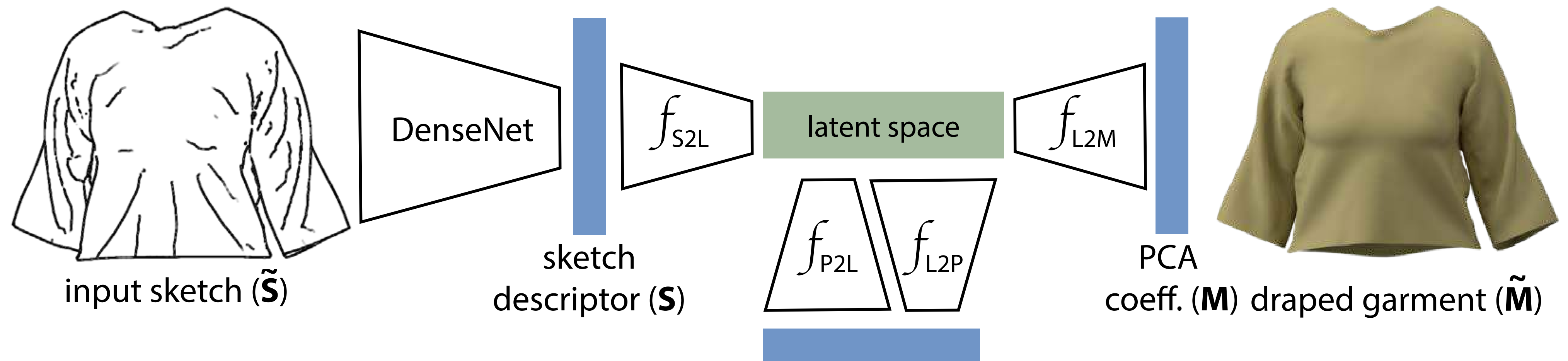
$$\|M - f_{L2M}(f_{S2L}(S))\|_2 \quad \|P - f_{L2P}(f_{S2L}(S))\|_2 \quad \|M - f_{L2M}(f_{P2L}(P))\|_2$$



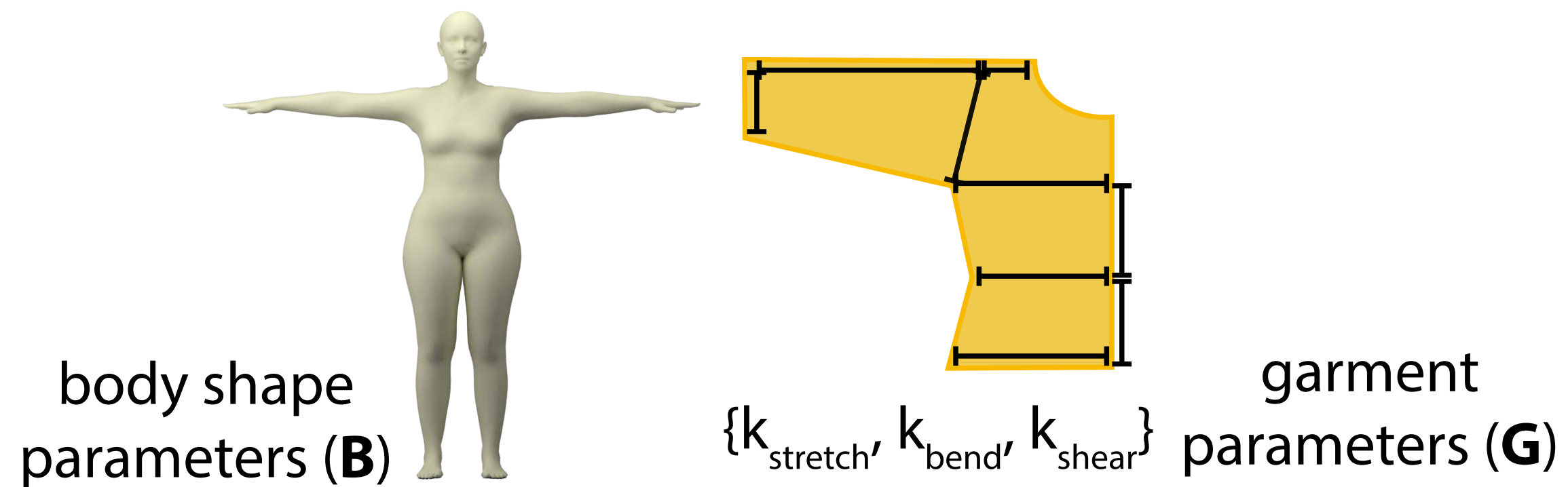
Details Refer to paper



$$\|M - f_{L2M}(f_{S2L}(S))\|_2 \quad \|P - f_{L2P}(f_{S2L}(S))\|_2 \quad \|M - f_{L2M}(f_{P2L}(P))\|_2 \quad \|P - f_{L2P}(f_{P2L}(P))\|_2$$



Details Refer to paper



$\mathcal{L}(\mathbf{P}, \mathbf{M}, \mathbf{S}) =$

$$\|M - f_{L2M}(f_{S2L}(S))\|_2 + \|P - f_{L2P}(f_{S2L}(S))\|_2 + \|M - f_{L2M}(f_{P2L}(P))\|_2 + \|P - f_{L2P}(f_{P2L}(P))\|_2$$

Sketch editing:

x4

The screenshot displays a 3D software interface titled "Viewer". The main workspace is divided into several sections:

- Top Left:** A 2D line drawing of a t-shirt.
- Top Right:** A green 2D shape representing a garment piece, outlined in red.
- Center:** A 3D model of a human figure with arms outstretched, rendered in a light tan color.
- Right:** A larger 3D model of a human figure with arms outstretched, rendered in a dark grey color, representing the final garmented model.

At the bottom, there are four control panels:

- Sketch Panel:** Contains buttons for "clear", "example 1", "example 2", "Draw", "Erase", "input", and "npr". It also has a "Select Template" dropdown and "Pen Mode" and "sketch Mode" options. At the bottom are "Run", "Clear", "Undo", and "Transfer" buttons.
- BodyShape Panel:** Contains a "predicted_body" dropdown and a "Select body" dropdown. Below it are "target_body_1", "target_body_2", and "target_body_3" options.
- Garment Panel:** Features an "Update Garment" button and five sliders for "Garment Parameter 1" through "Garment Parameter 5".
- Texture Panel:** Contains a "Rotation" slider, "X Translat" and "Y Translat" sliders, a "Scale" slider, and a "Select Tex" dropdown with options for "no texture", "texture 1", and "texture 2".
- 3D Panel:** Displays "fps: (9.575079)", "Camera distance" slider, "Light rotation" slider, and "R:114", "G:144", "B:154" color values. It also has a "clear color" button and "Front View", "Side View", and "Clothes" buttons.

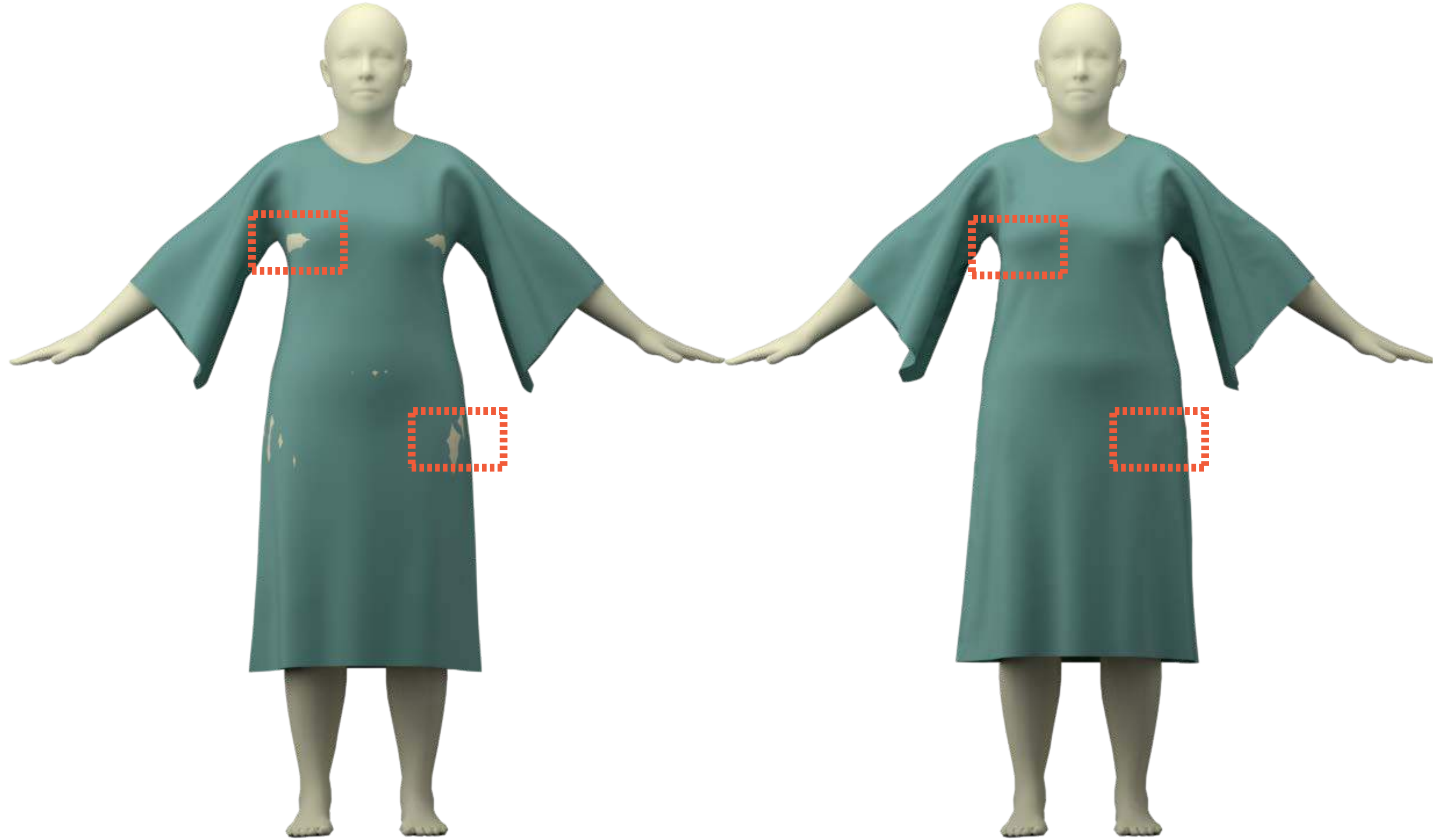
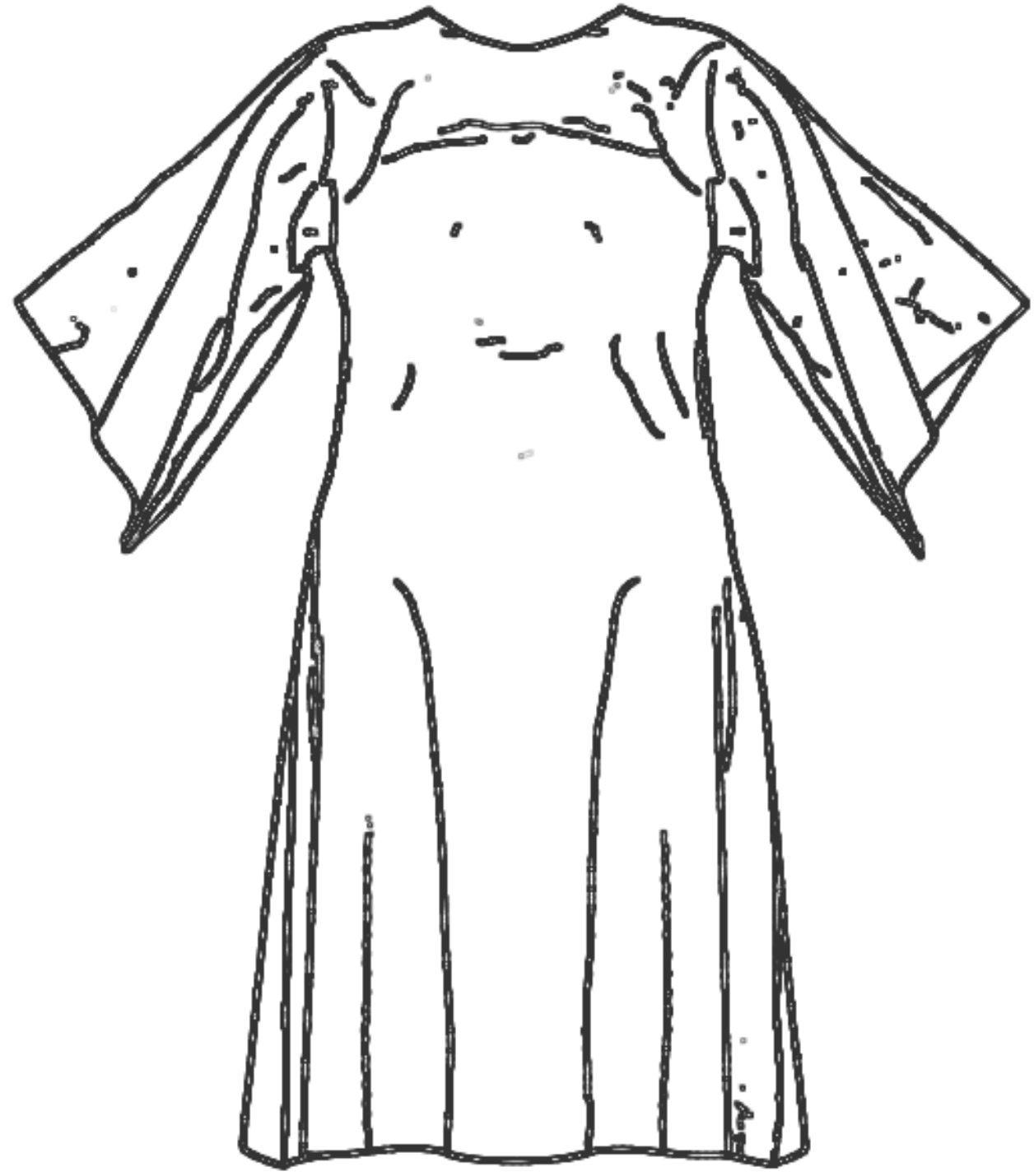
Sketch editing:

x4

The screenshot displays a software interface for sketch editing, titled "Viewer". The main workspace is divided into several sections:

- Sketch Panel:** Contains a 2D line drawing of a t-shirt. Below it are controls for "Select Template" (with options: clear, example 1, example 2), "Pen Mode" (with options: Draw, Erase), and "sketch Mode" (with options: input, npr). At the bottom are buttons for Run, Clear, Undo, and Transfer.
- BodyShape Panel:** Features a "predicted_body" dropdown and a "Select body" button. Below are target body options: target_body_1, target_body_2, target_body_3, and target_body_4.
- Garment Panel:** Includes an "Update Garment" button and five sliders for "Garment Parameter 1" through "Garment Parameter 5".
- Texture Panel:** Shows "Rotation" (0.359), "X Translat" (2.008), "Y Translat" (-3.448), and "Scale" (5.357). It also has a "Select Tex" dropdown with options: no texture, texture 1, and texture 2.
- 3D Panel:** Displays "fps: (9.575079)", "Camera distance" (0.888), "Light rotation" (6.438), and RGB values (R:114, G:144, B:154) with a "clear color" button. View options include "Front View", "Side View", and "Clothes".

The central 3D view shows a human figure with arms outstretched, wearing a grey t-shirt and tan pants. A smaller version of the same figure is visible in the background. A green L-shaped polygon is overlaid on the top right of the sketch area.

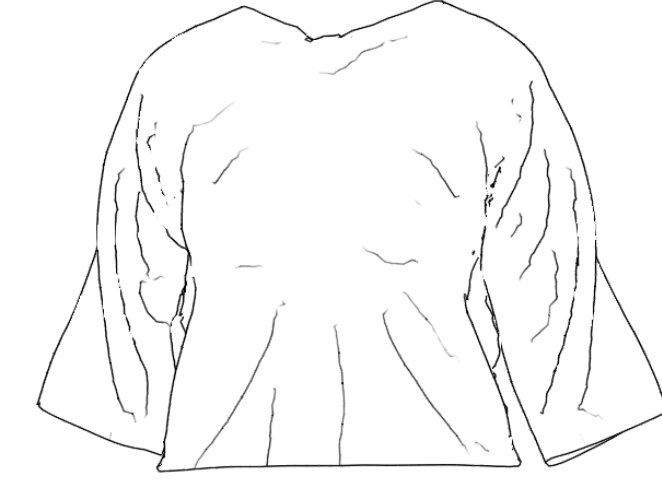
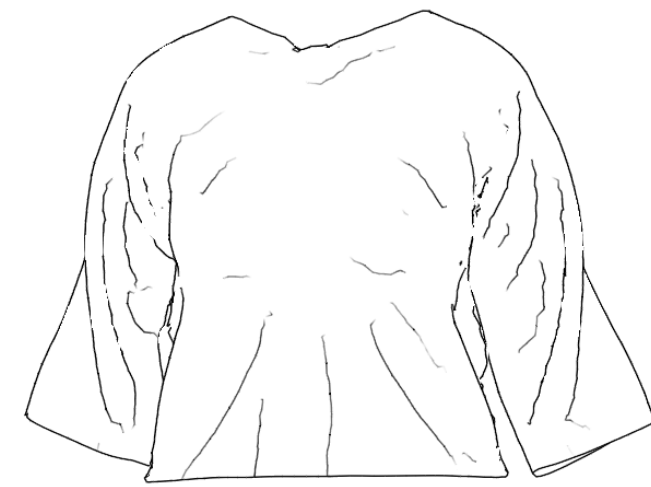


network output

simulated

User study on prediction accuracy

2D sketch



OR



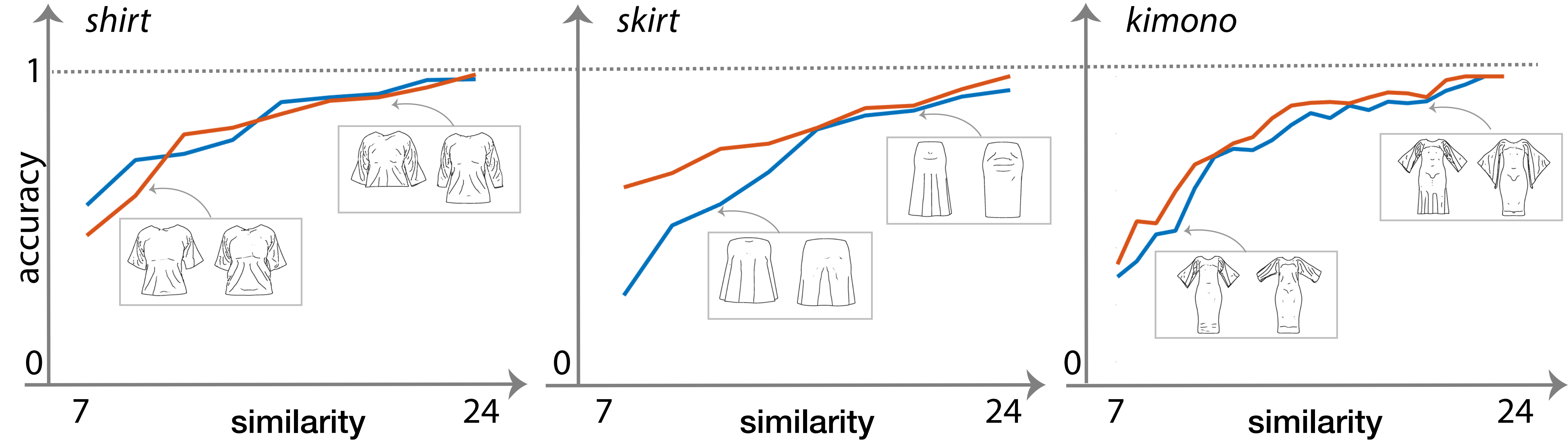
3D Shape



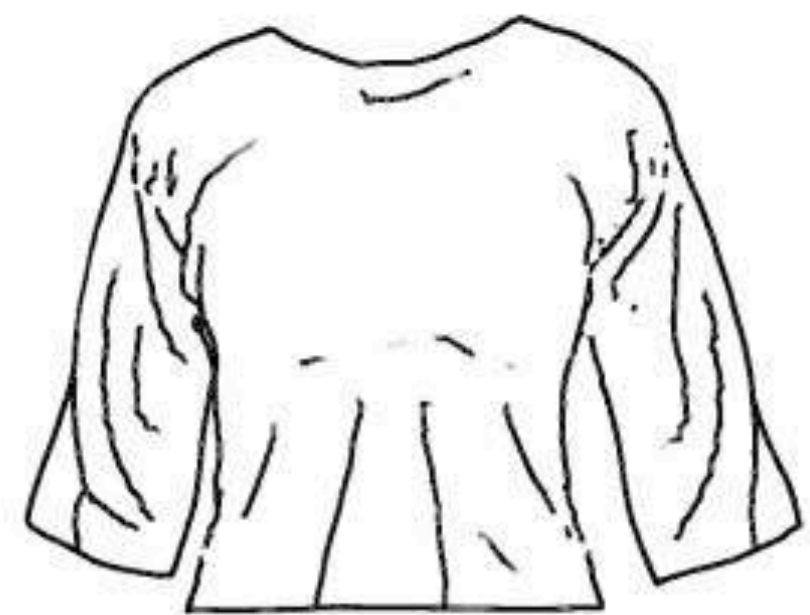
(correct)

(wrong)

User study on prediction accuracy



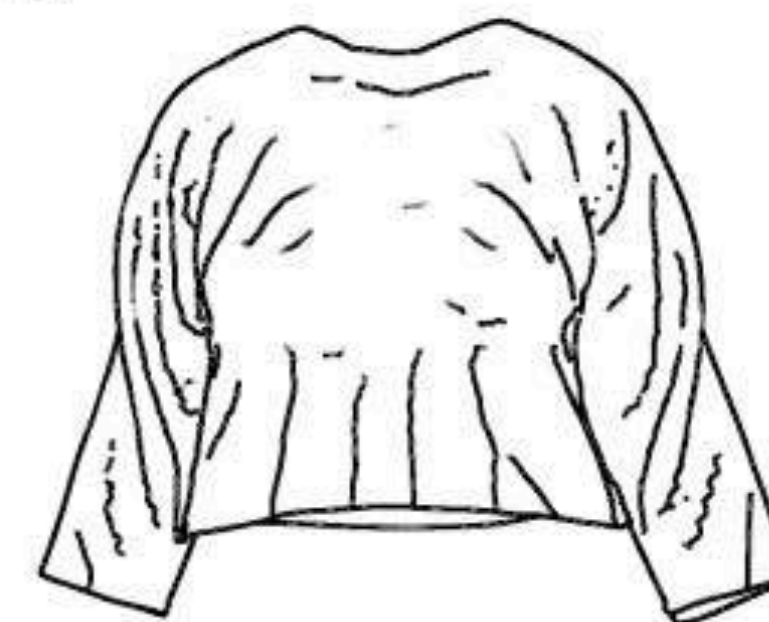
input sketch:



output (with and without texture):



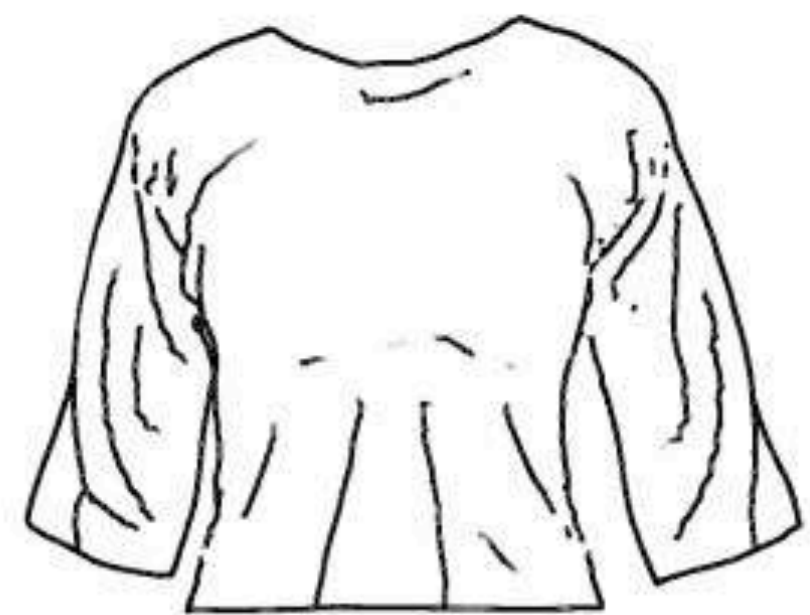
input sketch:



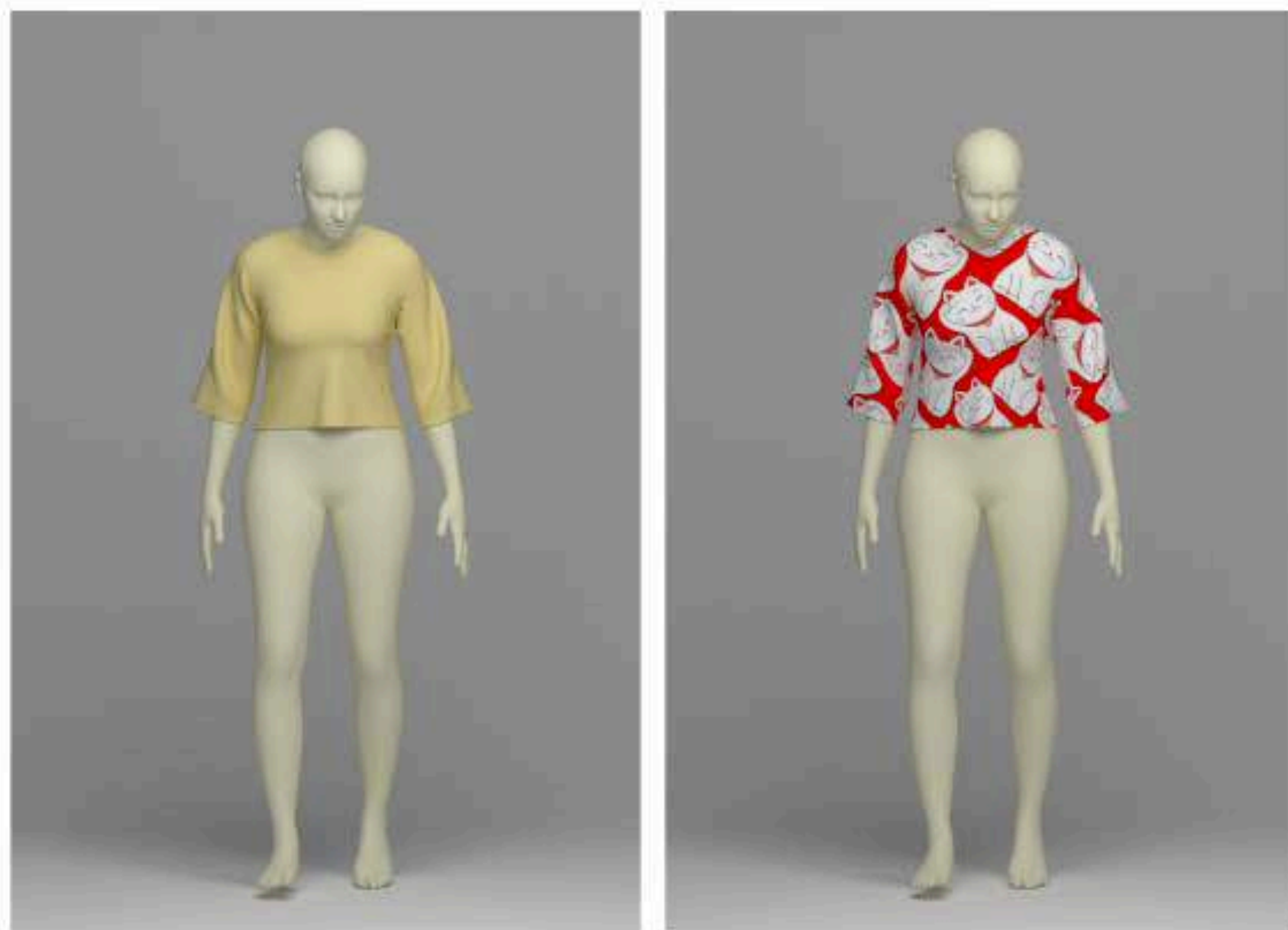
output (with and without texture):



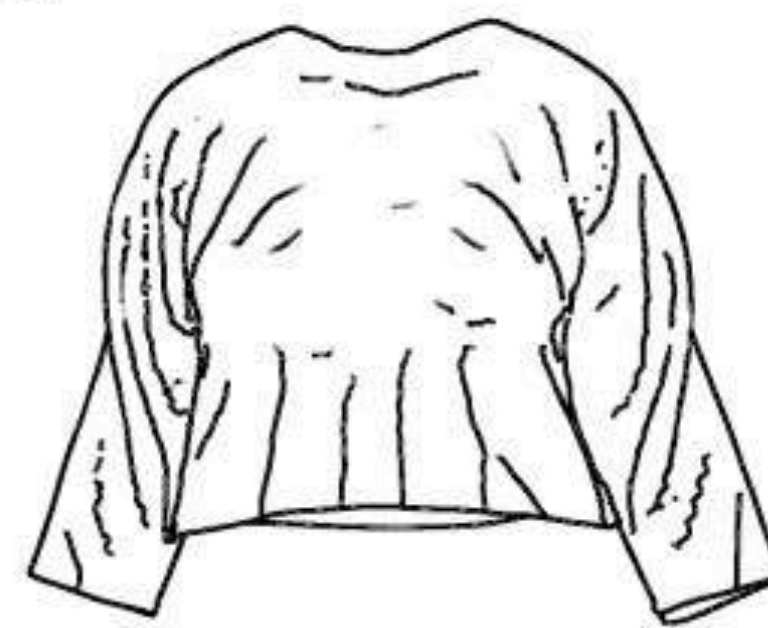
input sketch:



output (with and without texture):



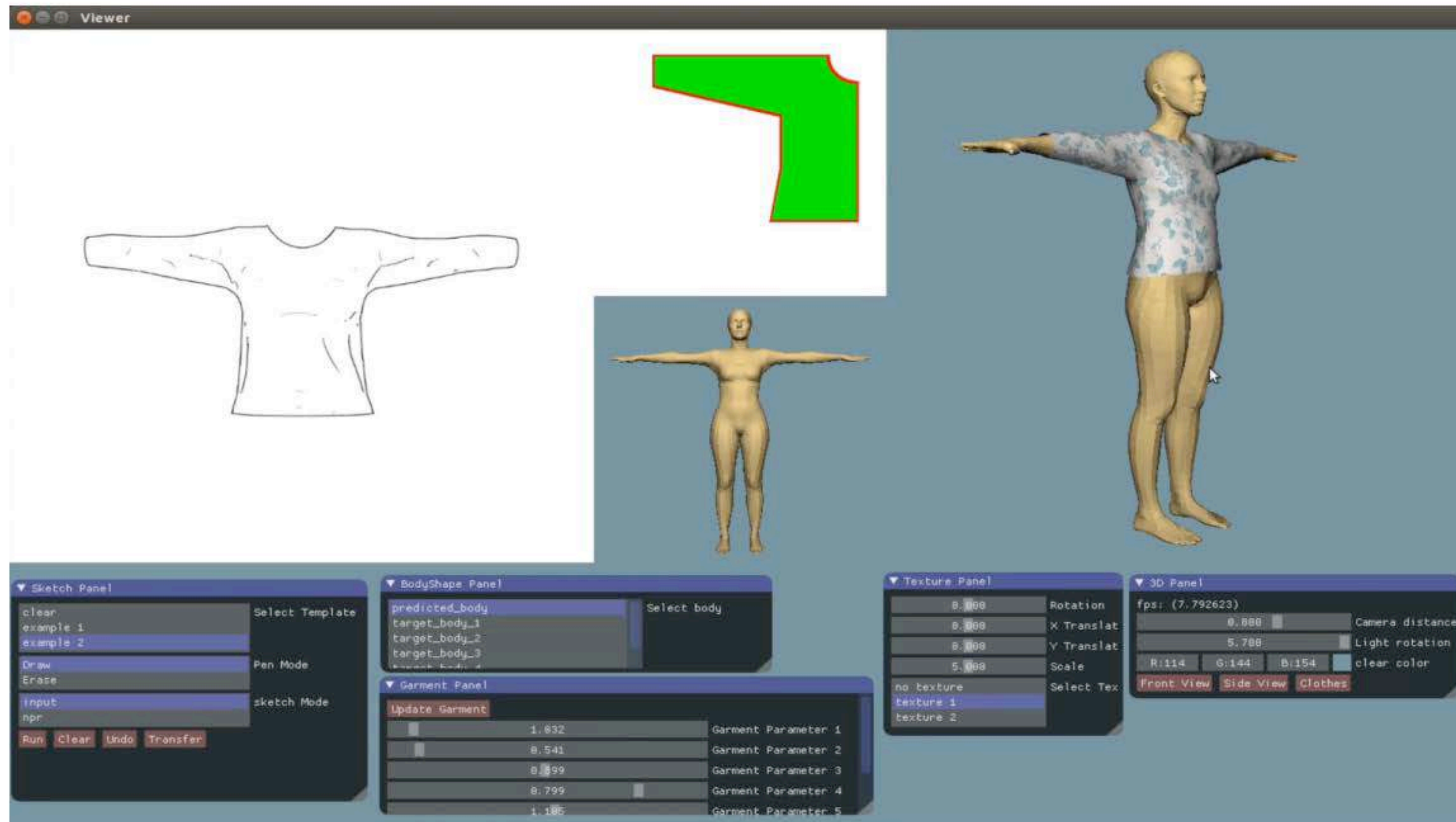
input sketch:



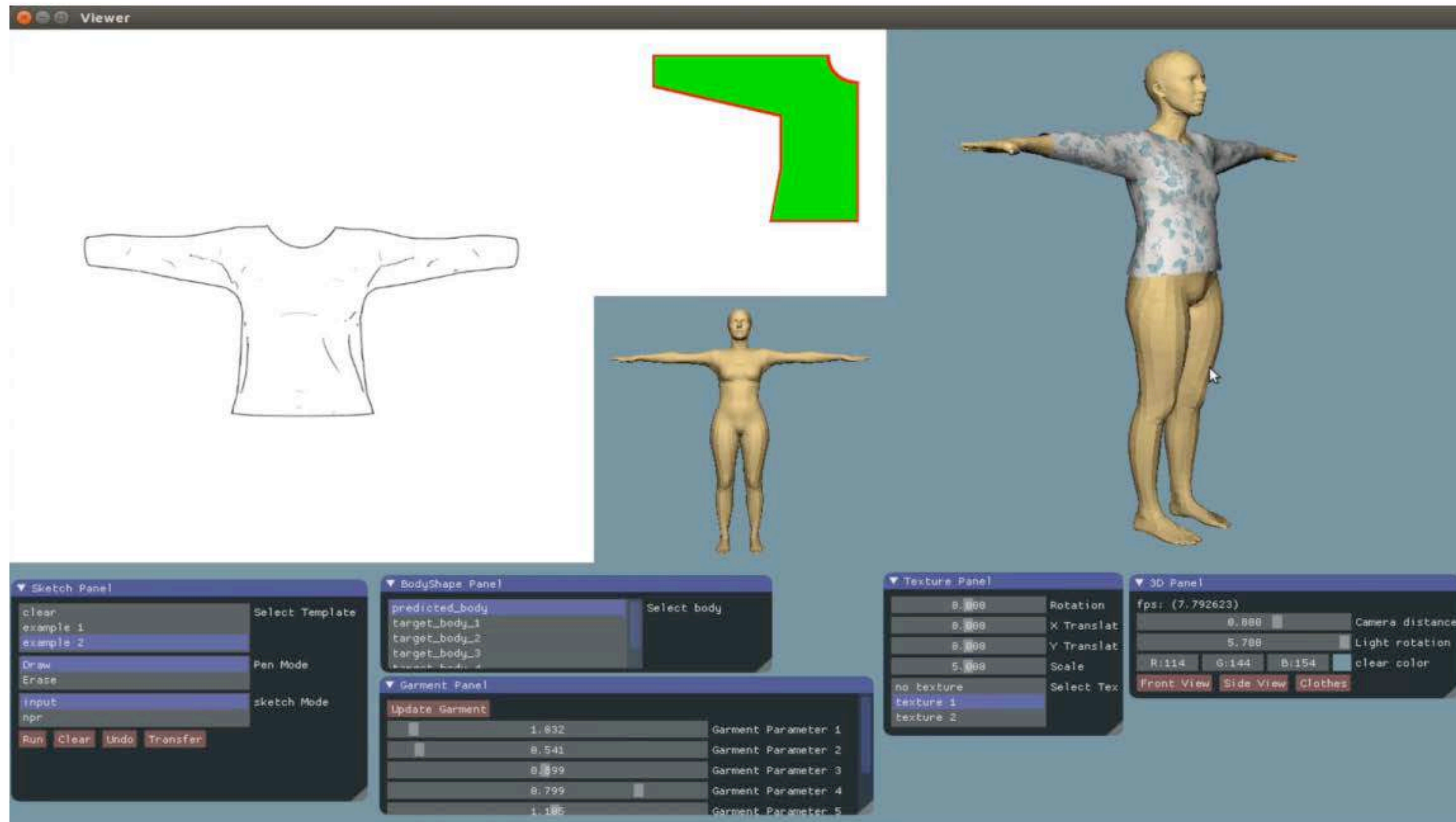
output (with and without texture):



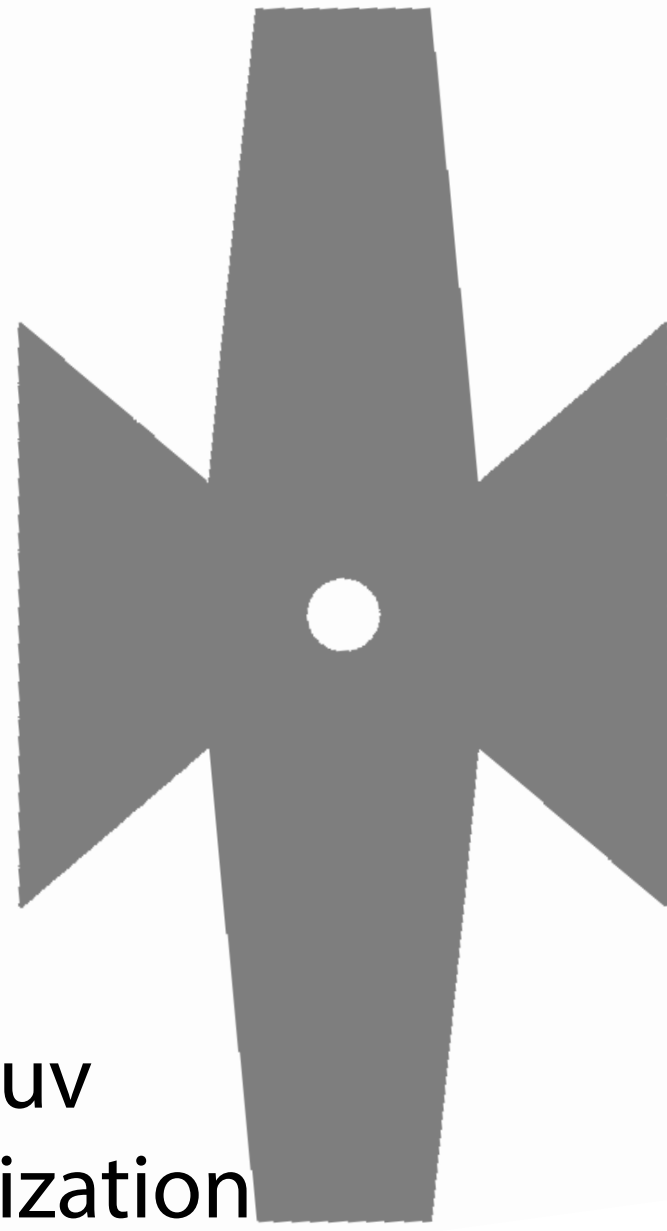
Retexturing:



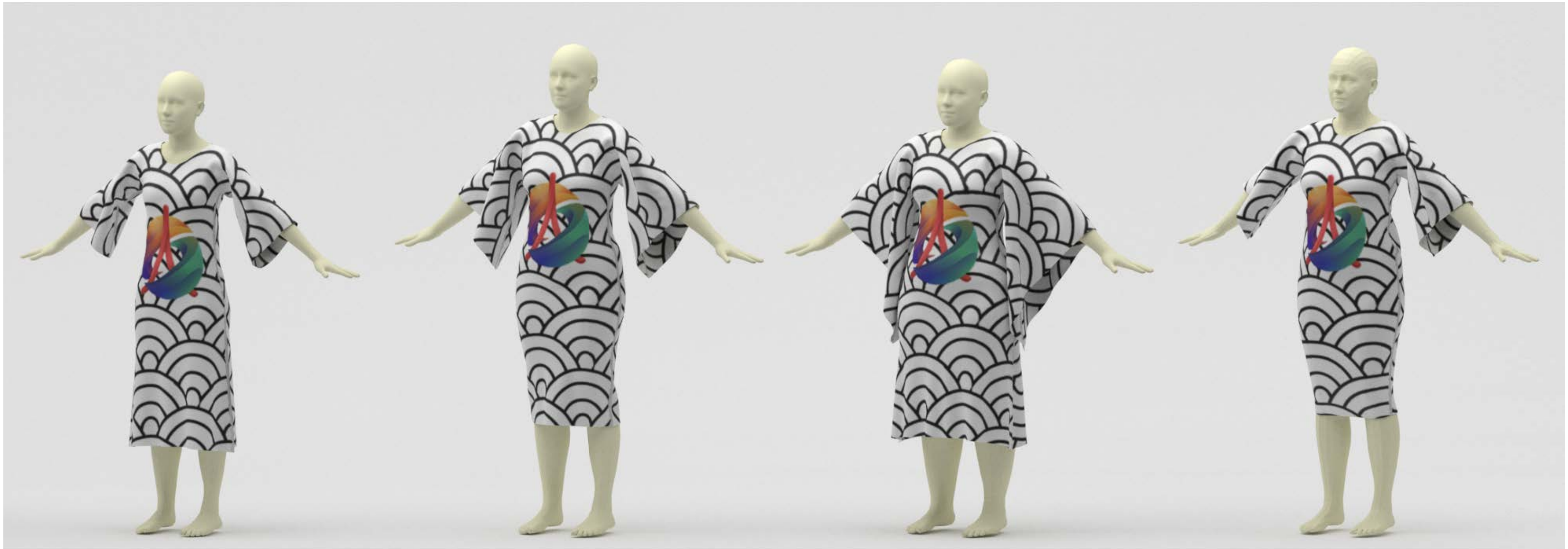
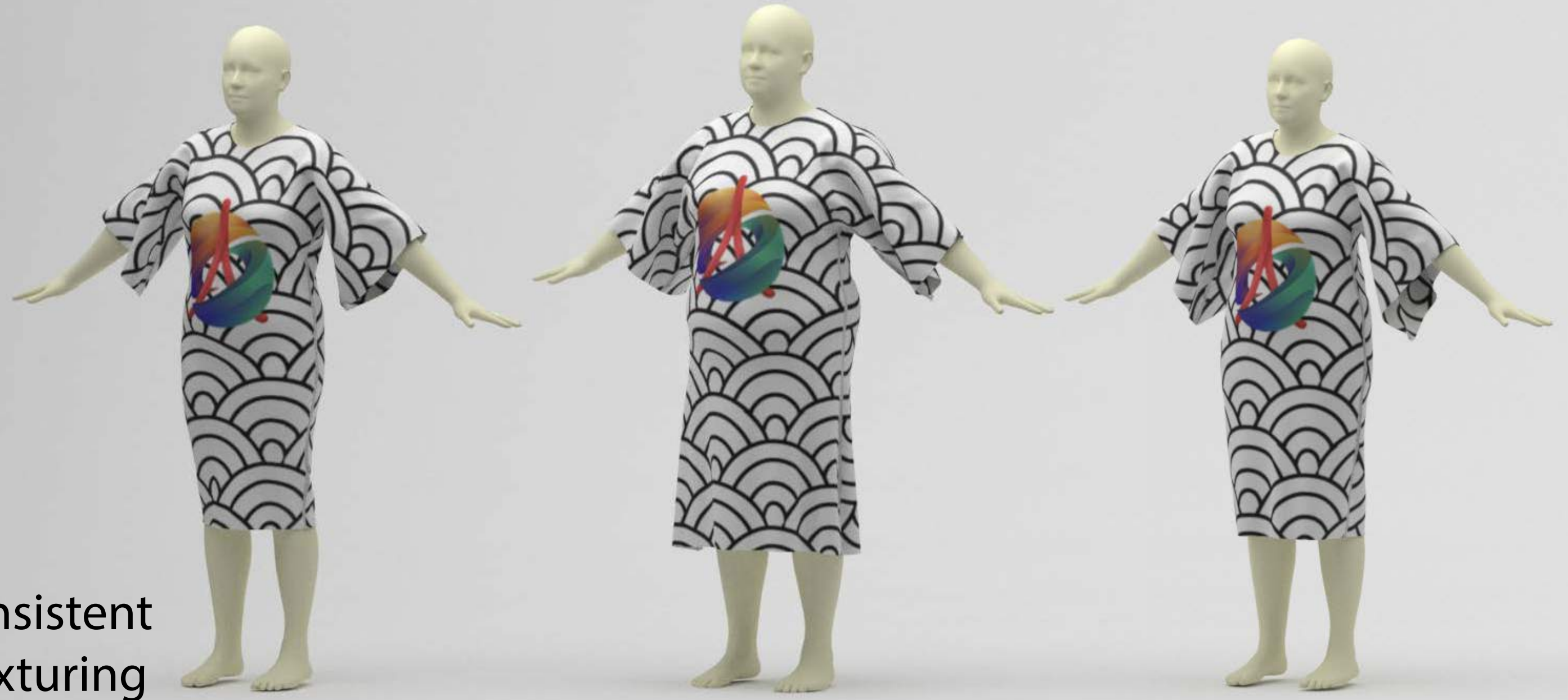
Retexturing:

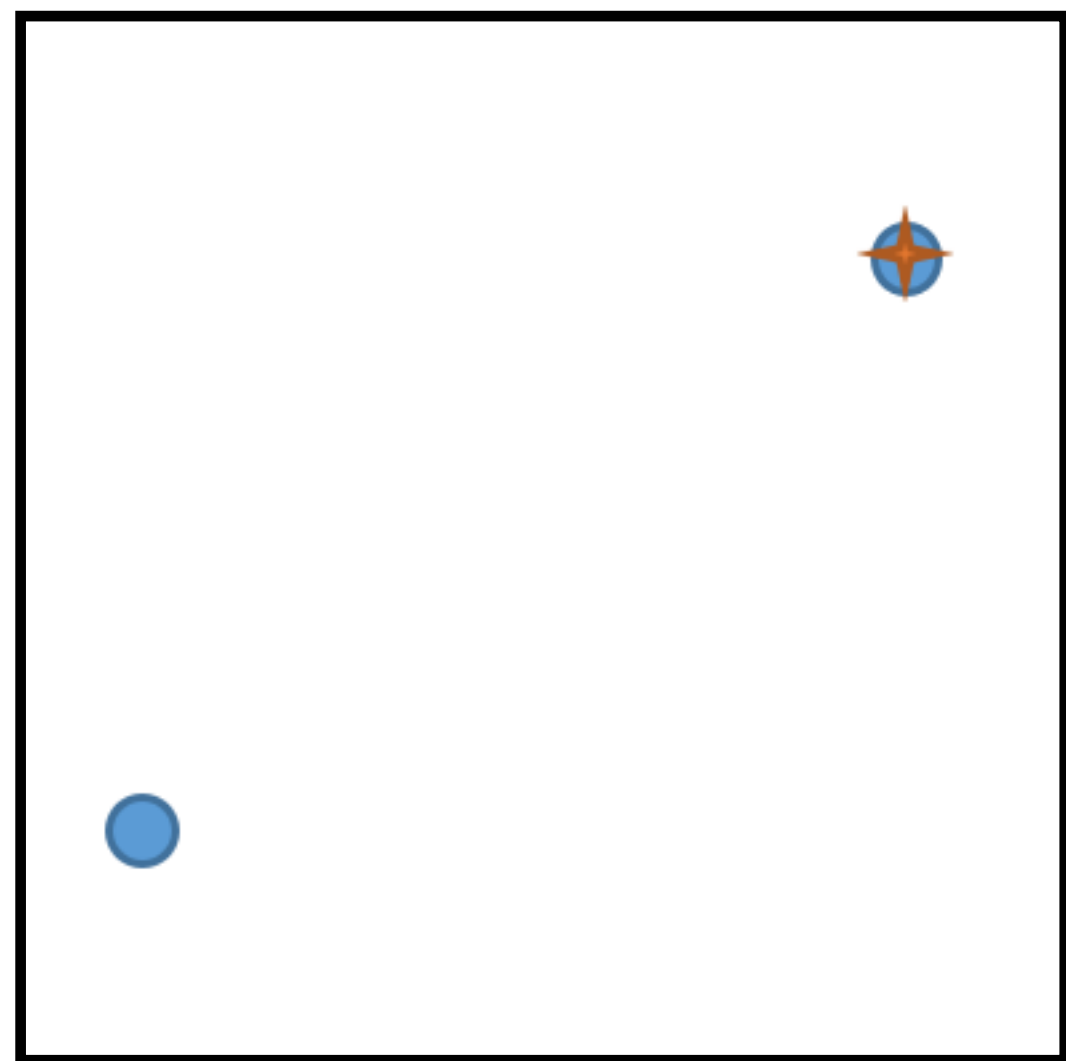
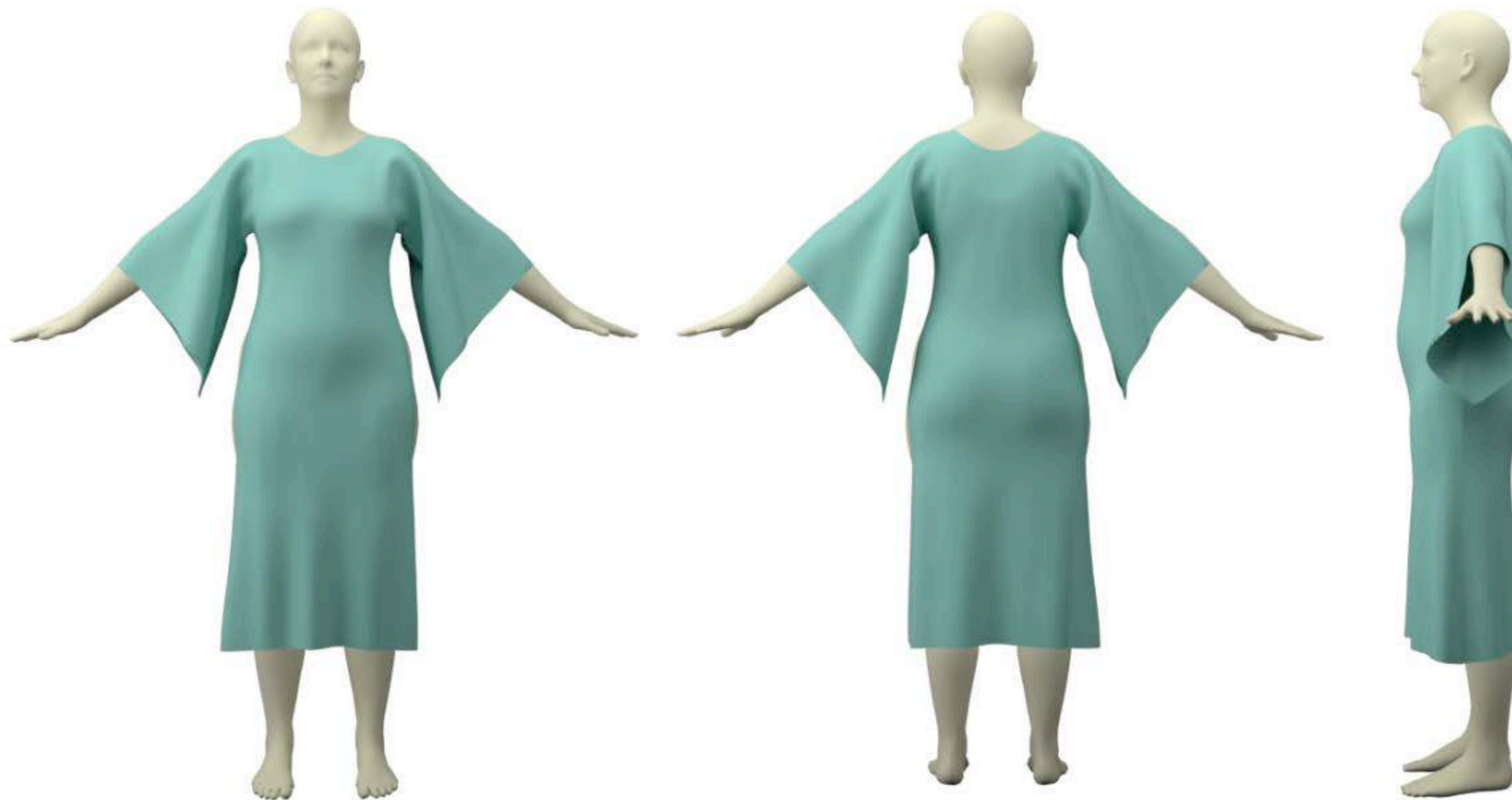
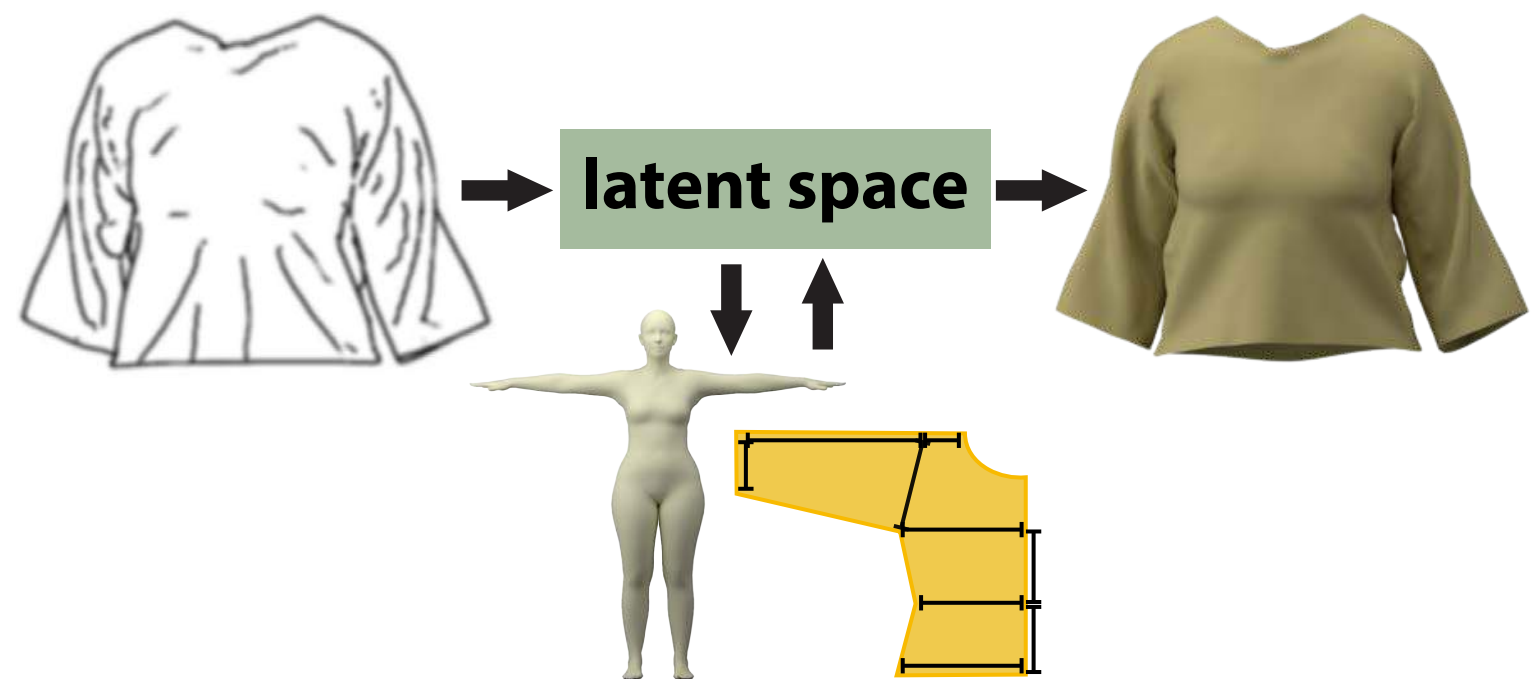


recovered uv
parameterization

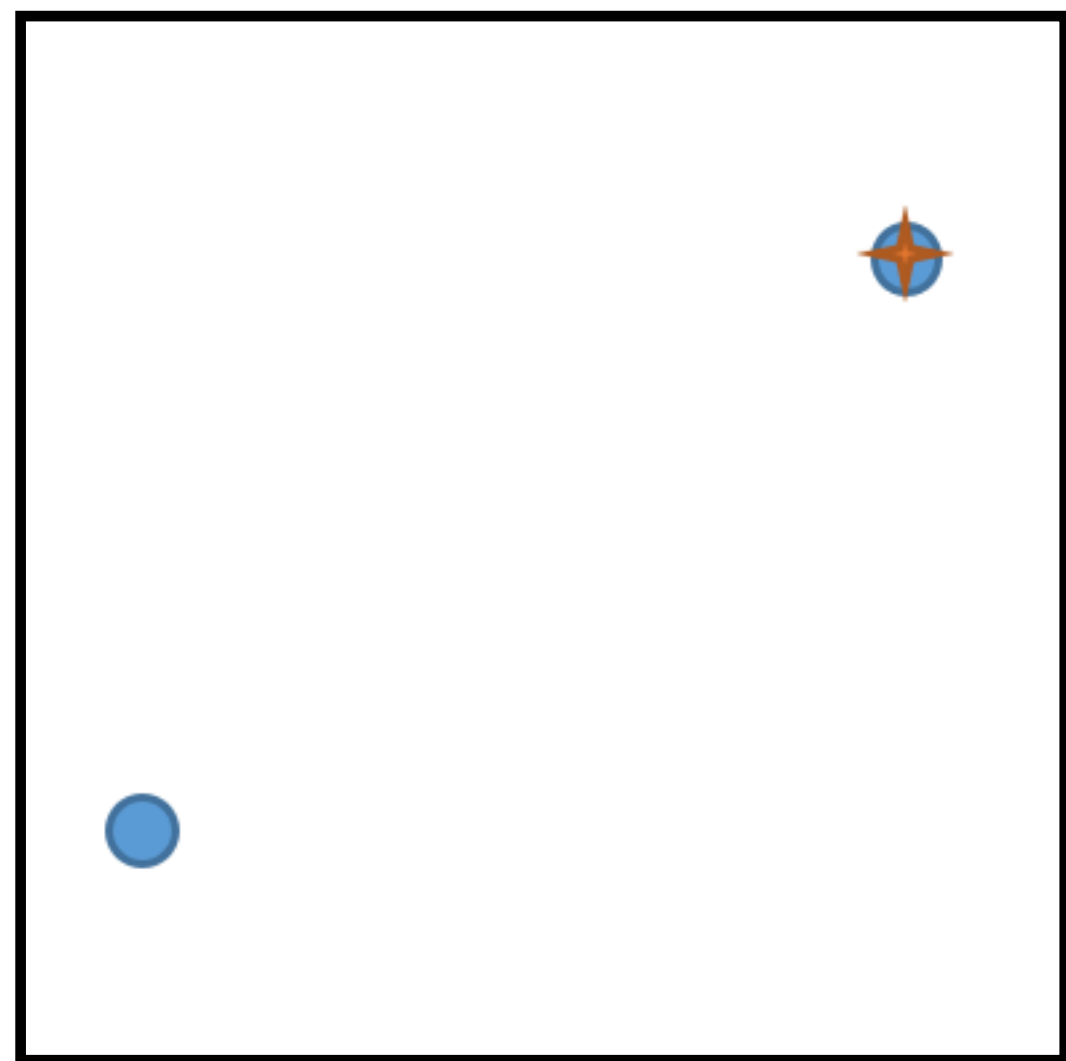
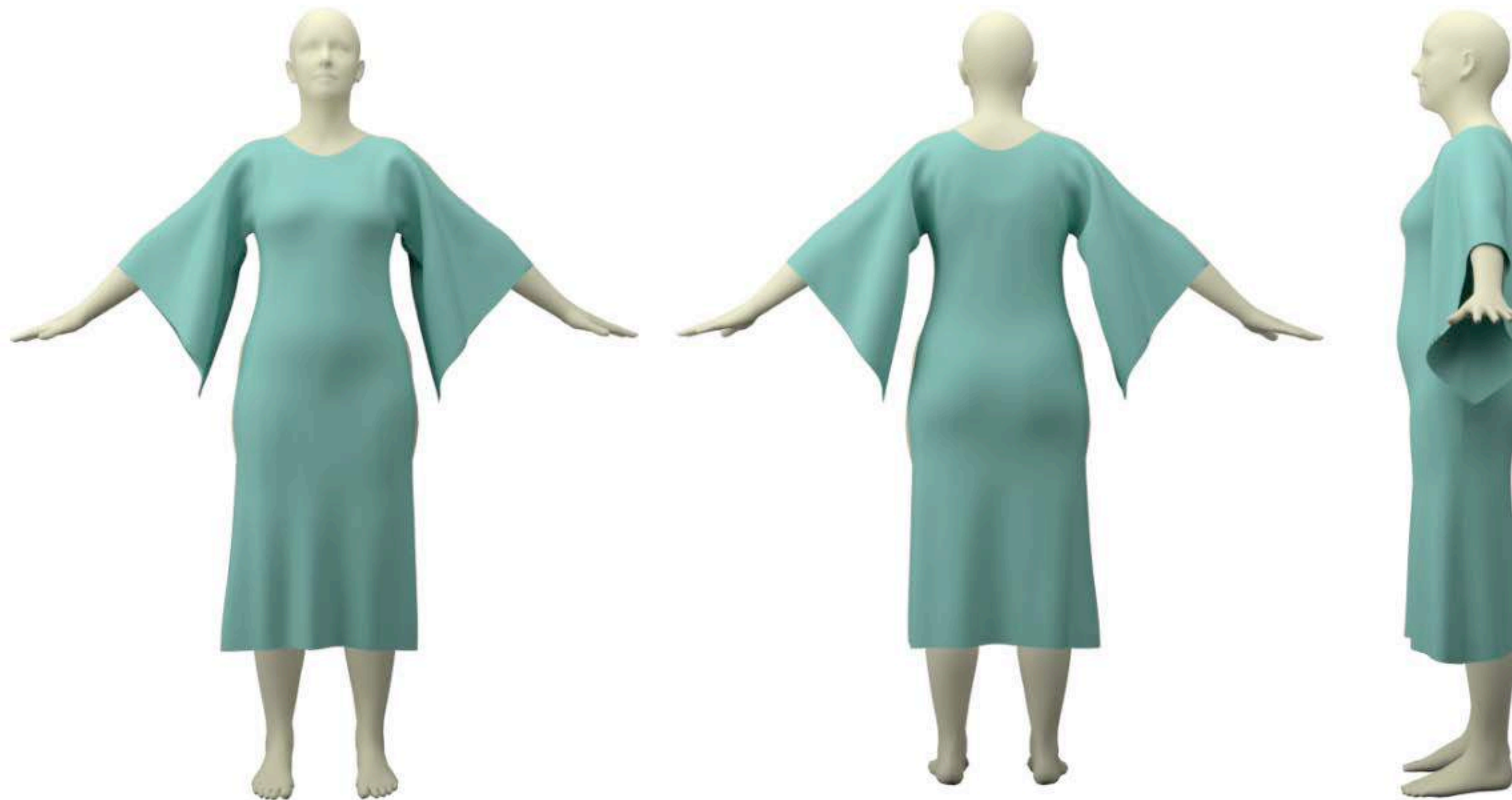
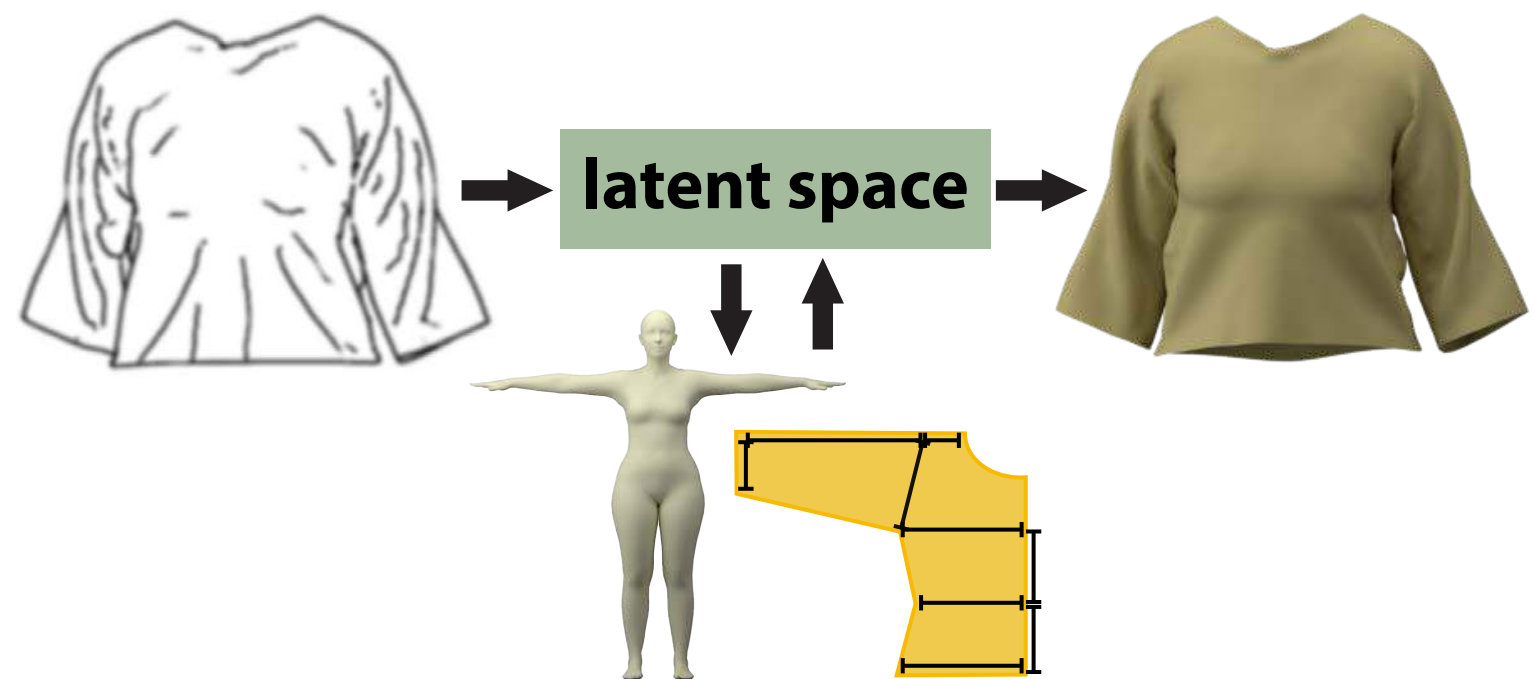


consistent
texturing





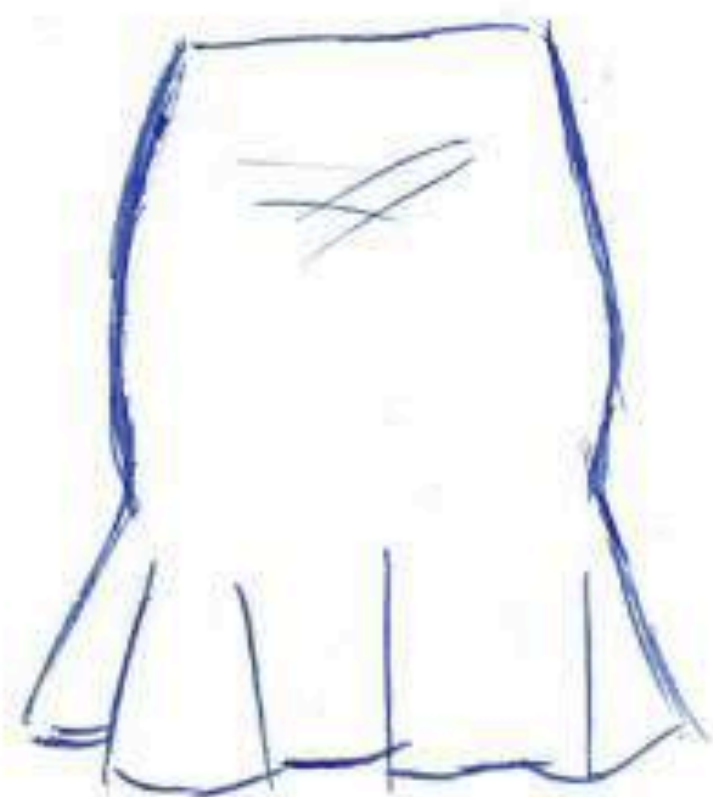
Latent Space



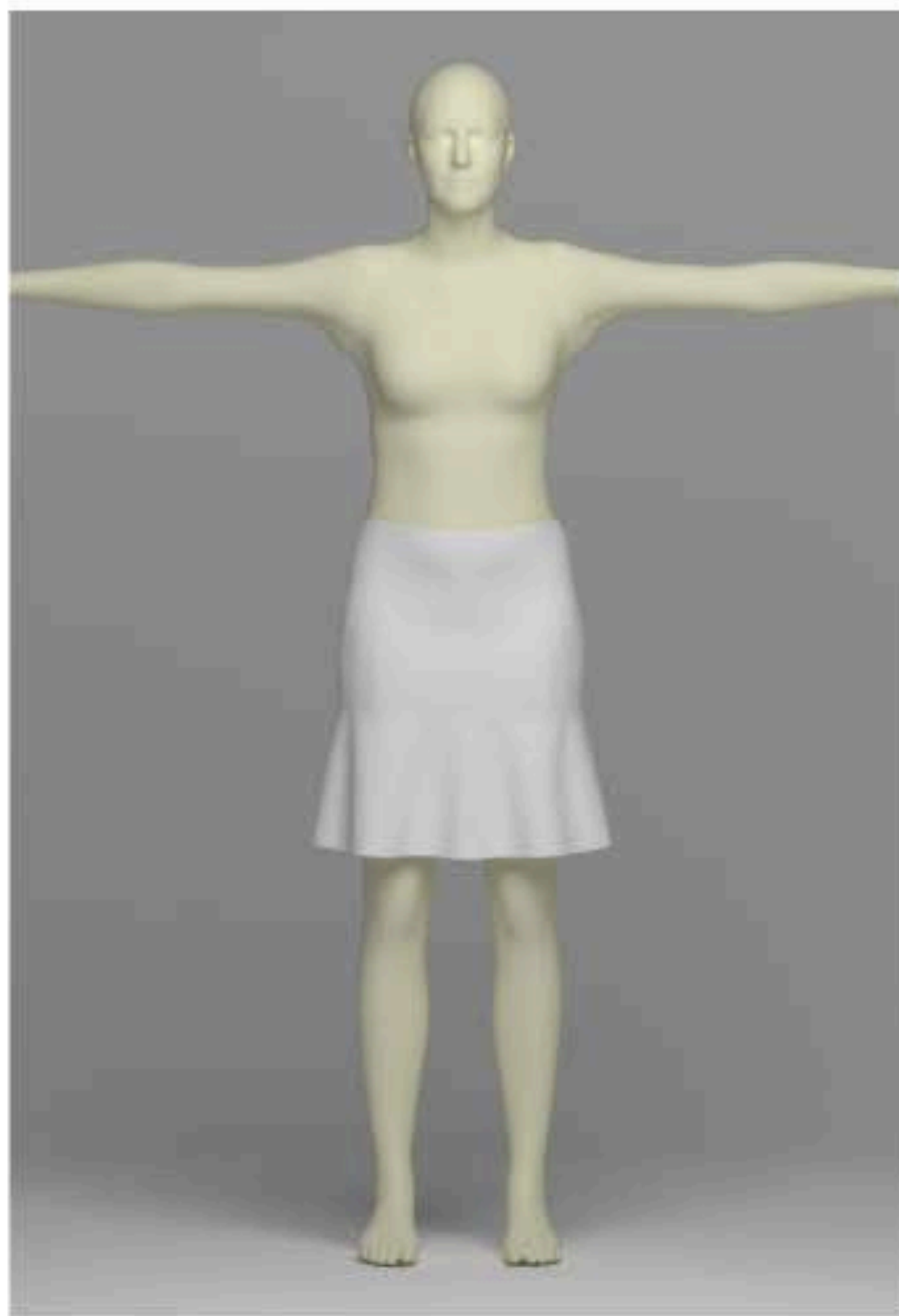
Latent Space



reference image



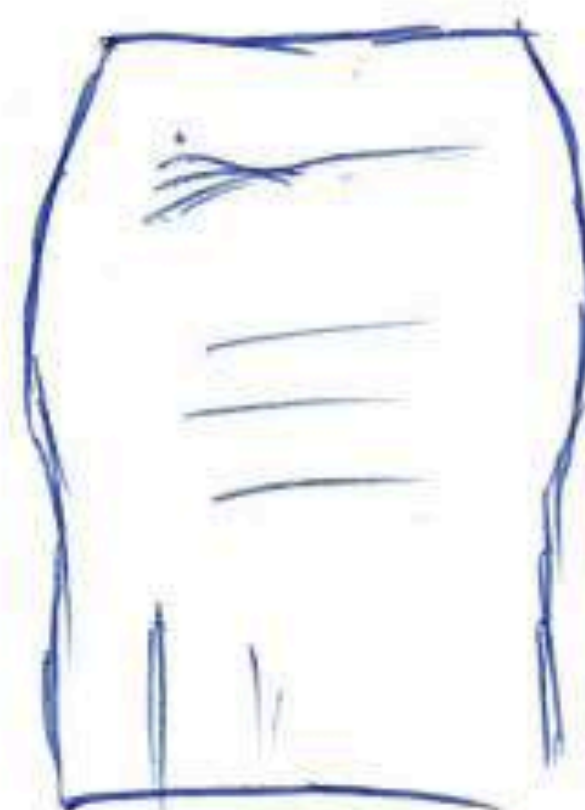
input sketch



output



reference image



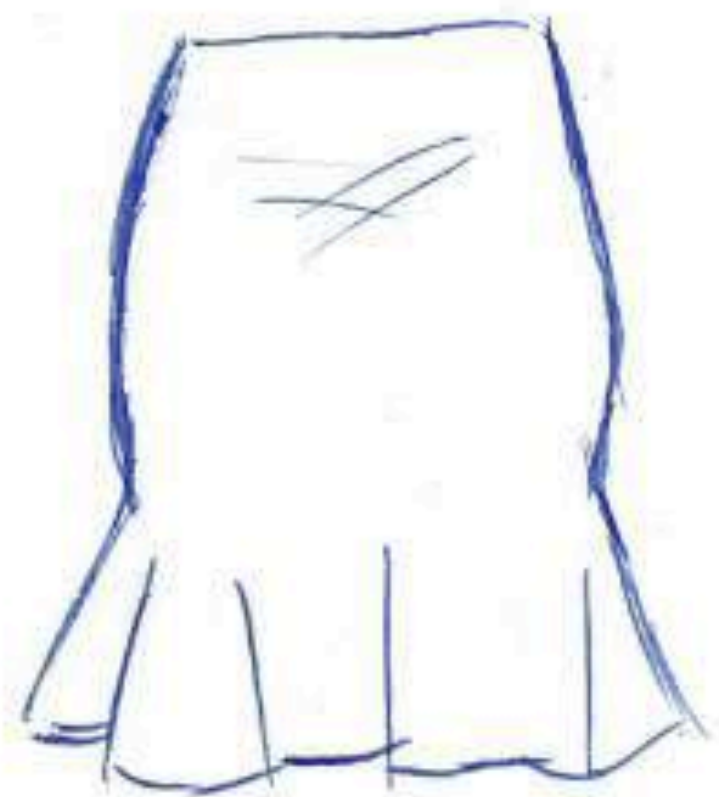
input sketch



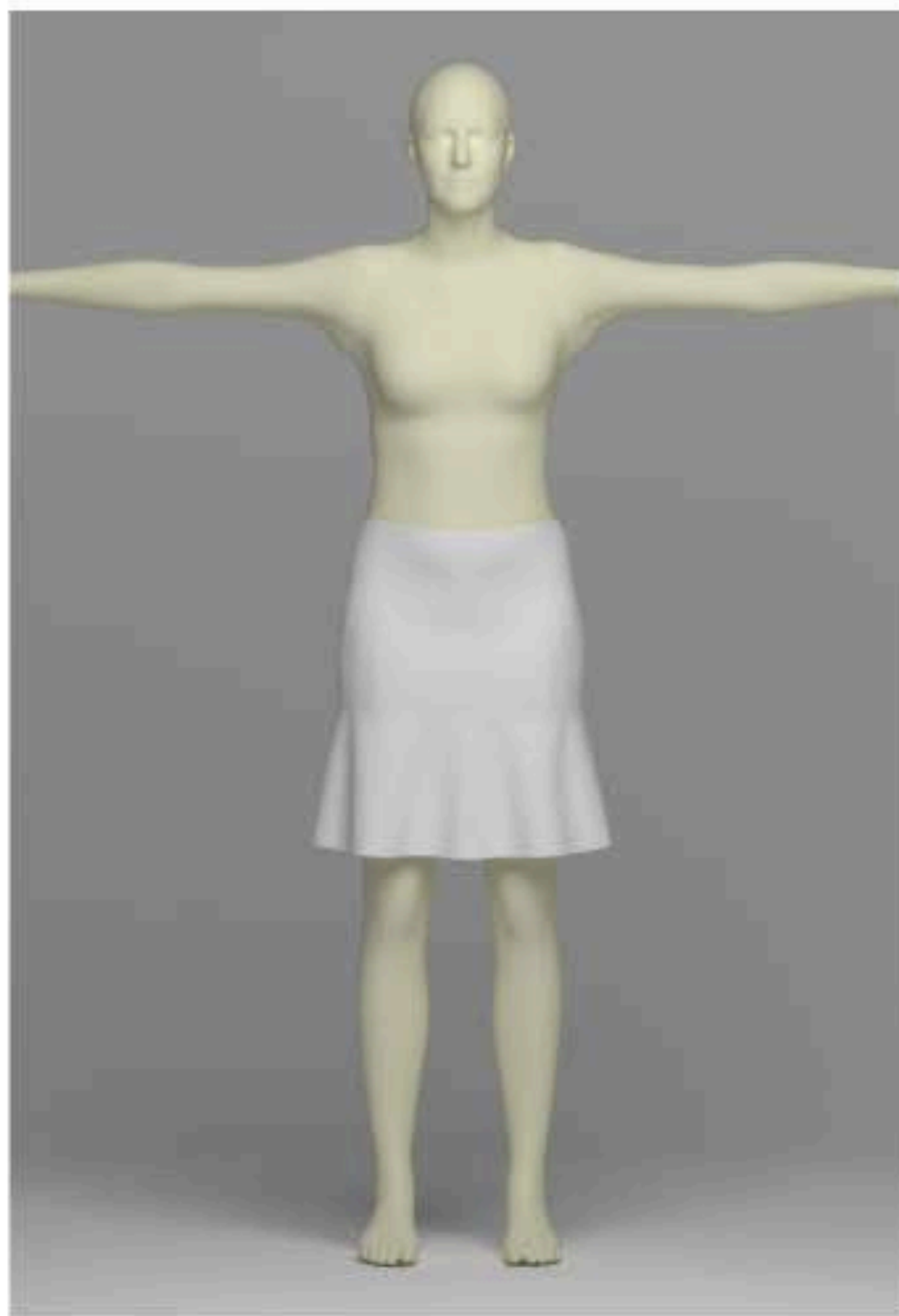
output



reference image



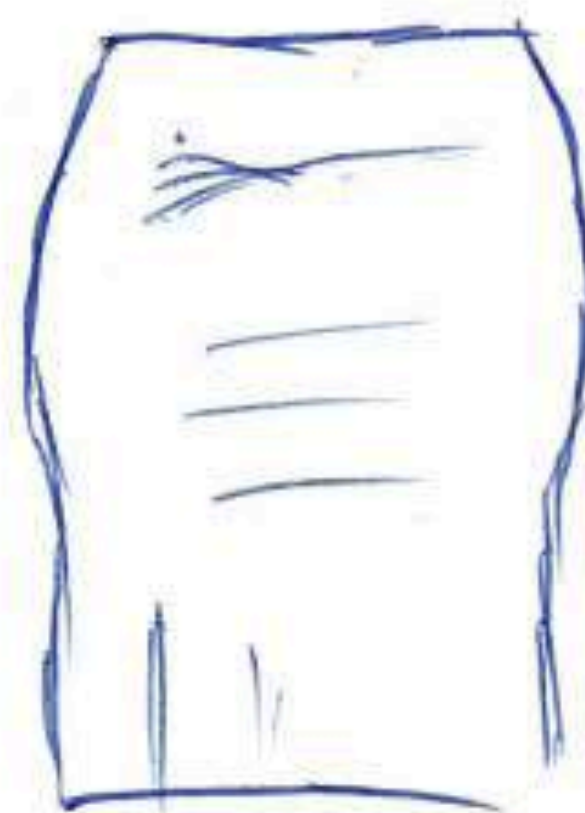
input sketch



output



reference image

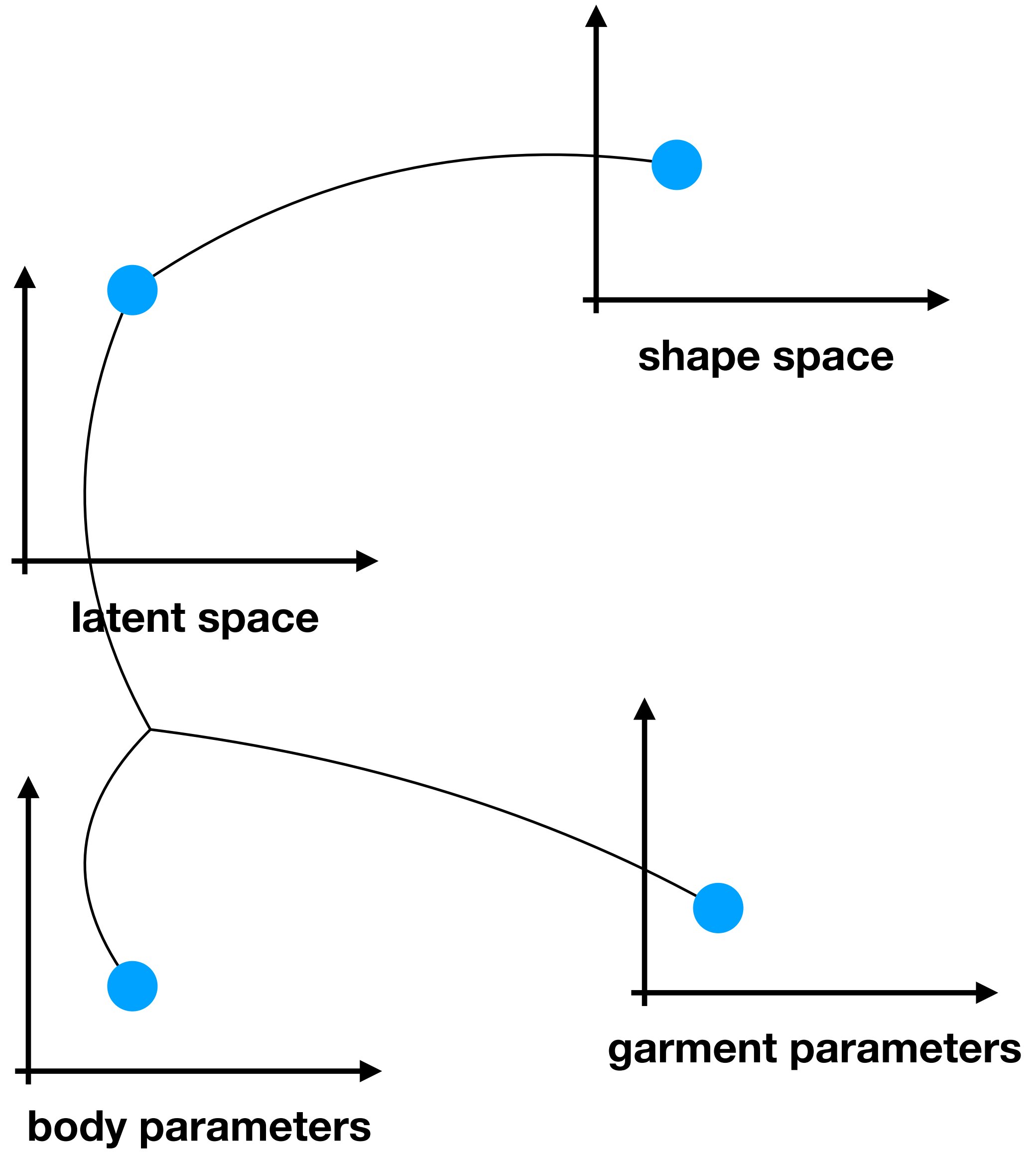


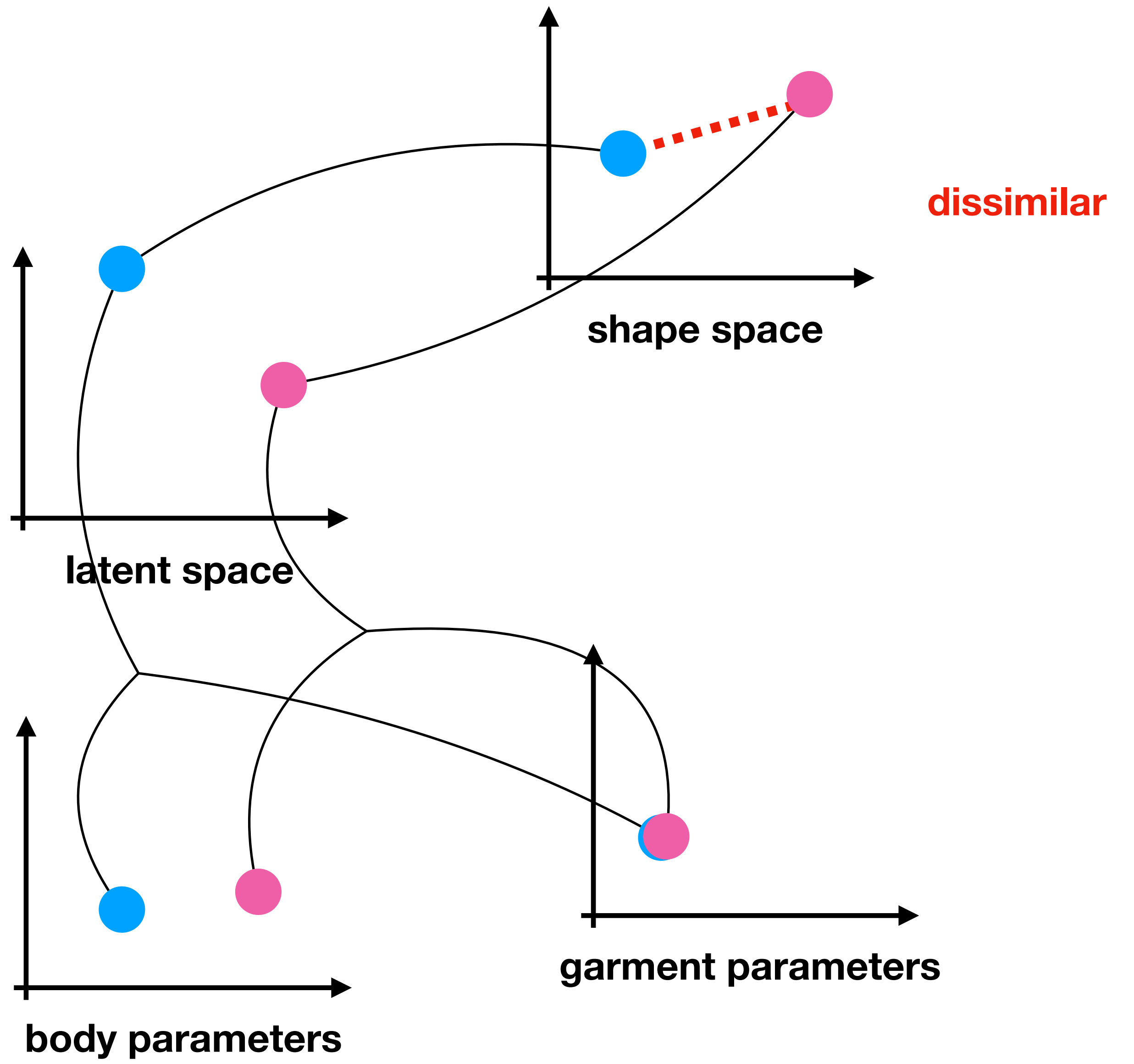
input sketch

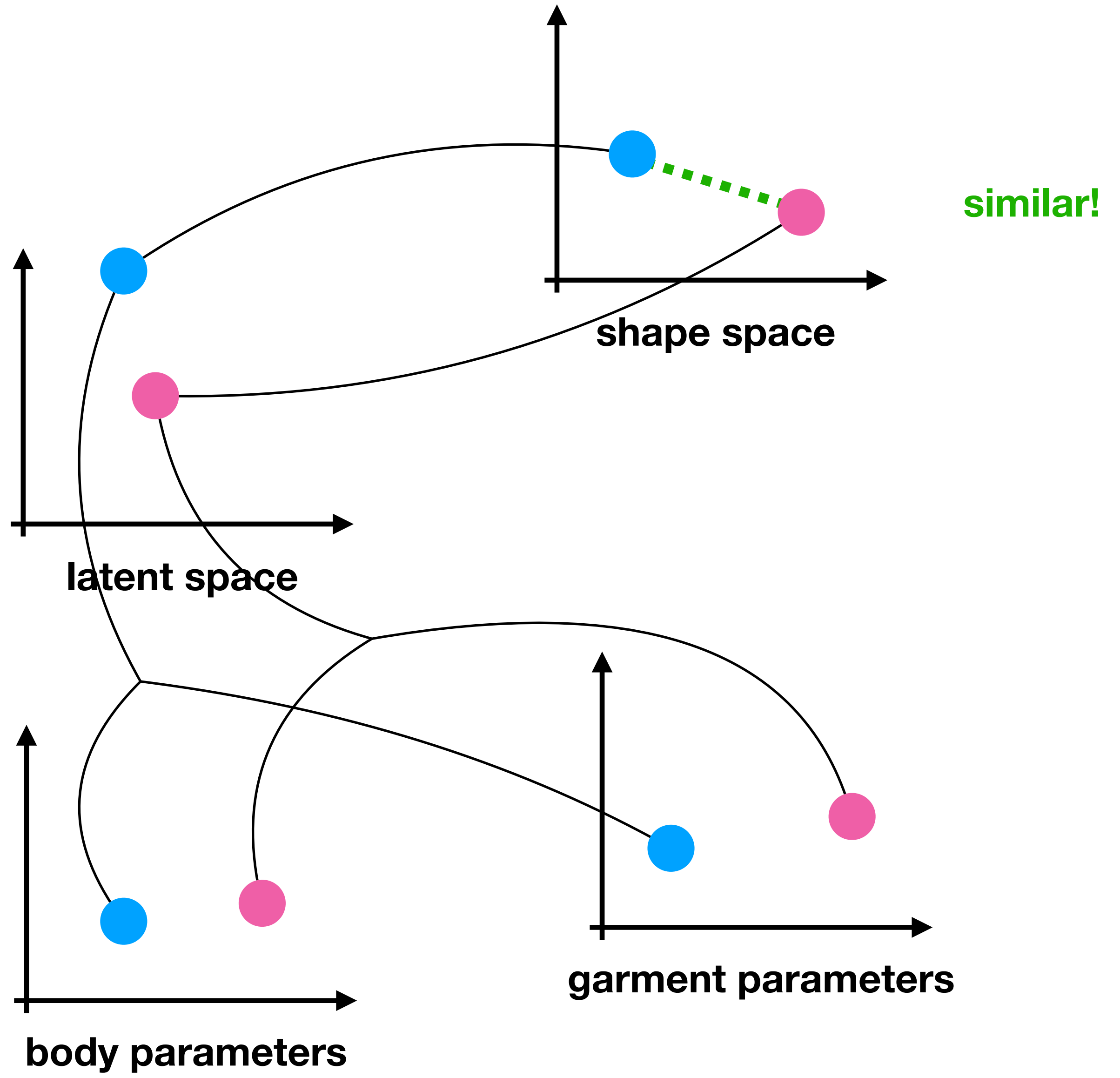


output



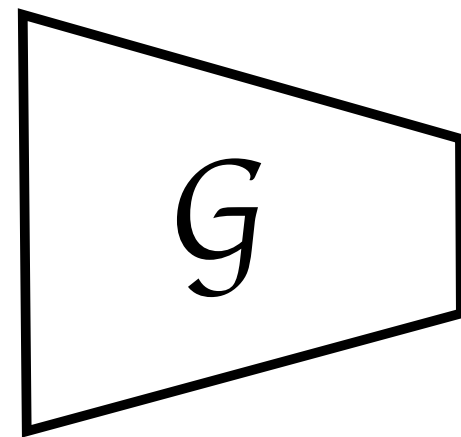




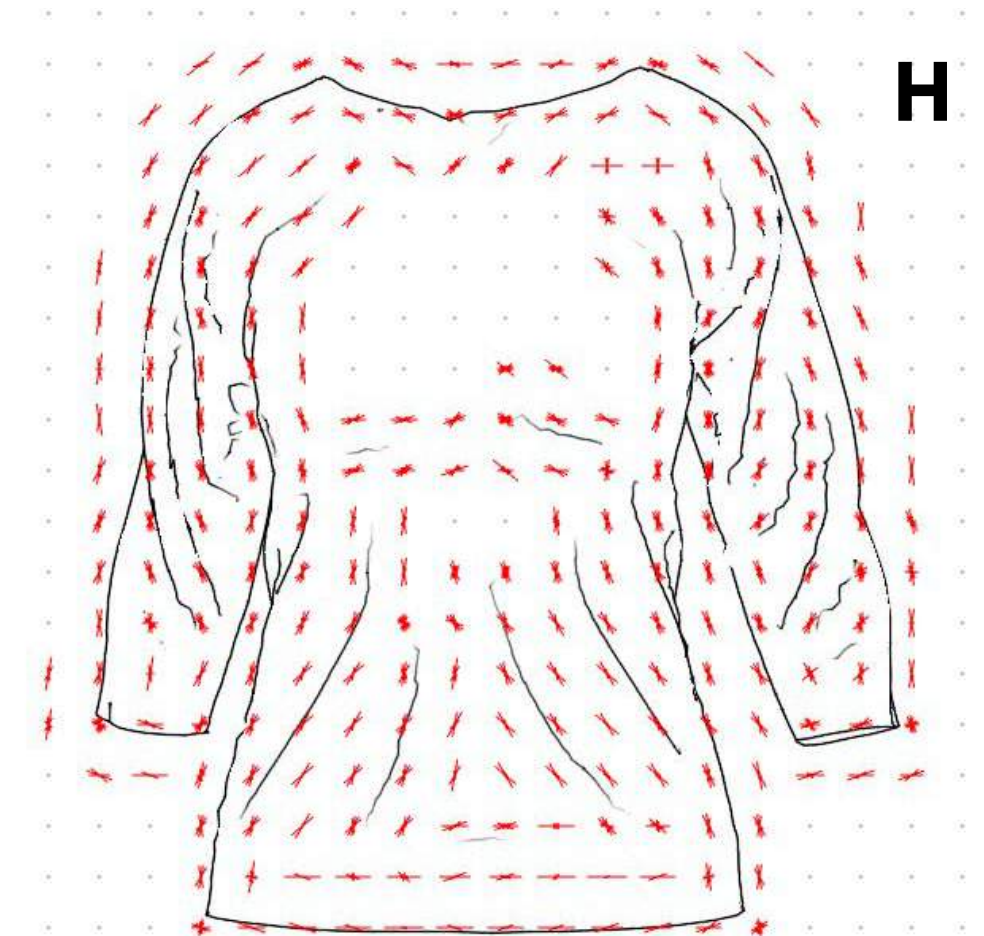




M



$G(M)$

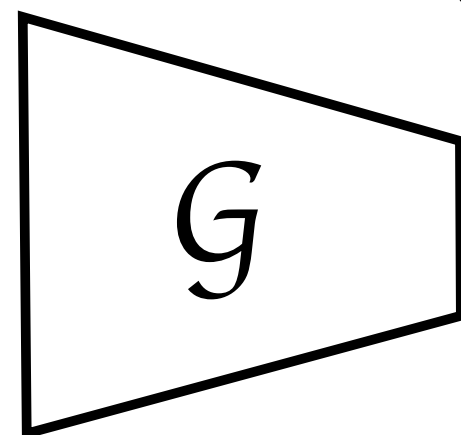


H

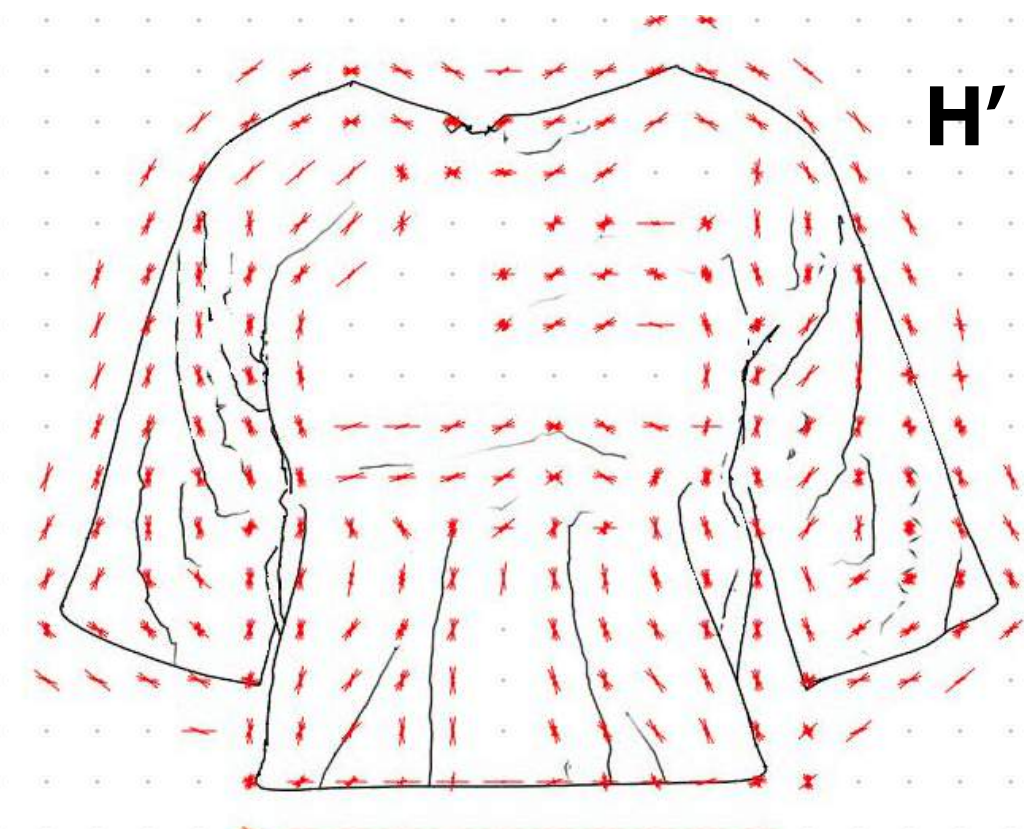
$$\|G(M)-G(M')\| \xleftrightarrow{\text{Loss}} \|H-H'\|$$



M'



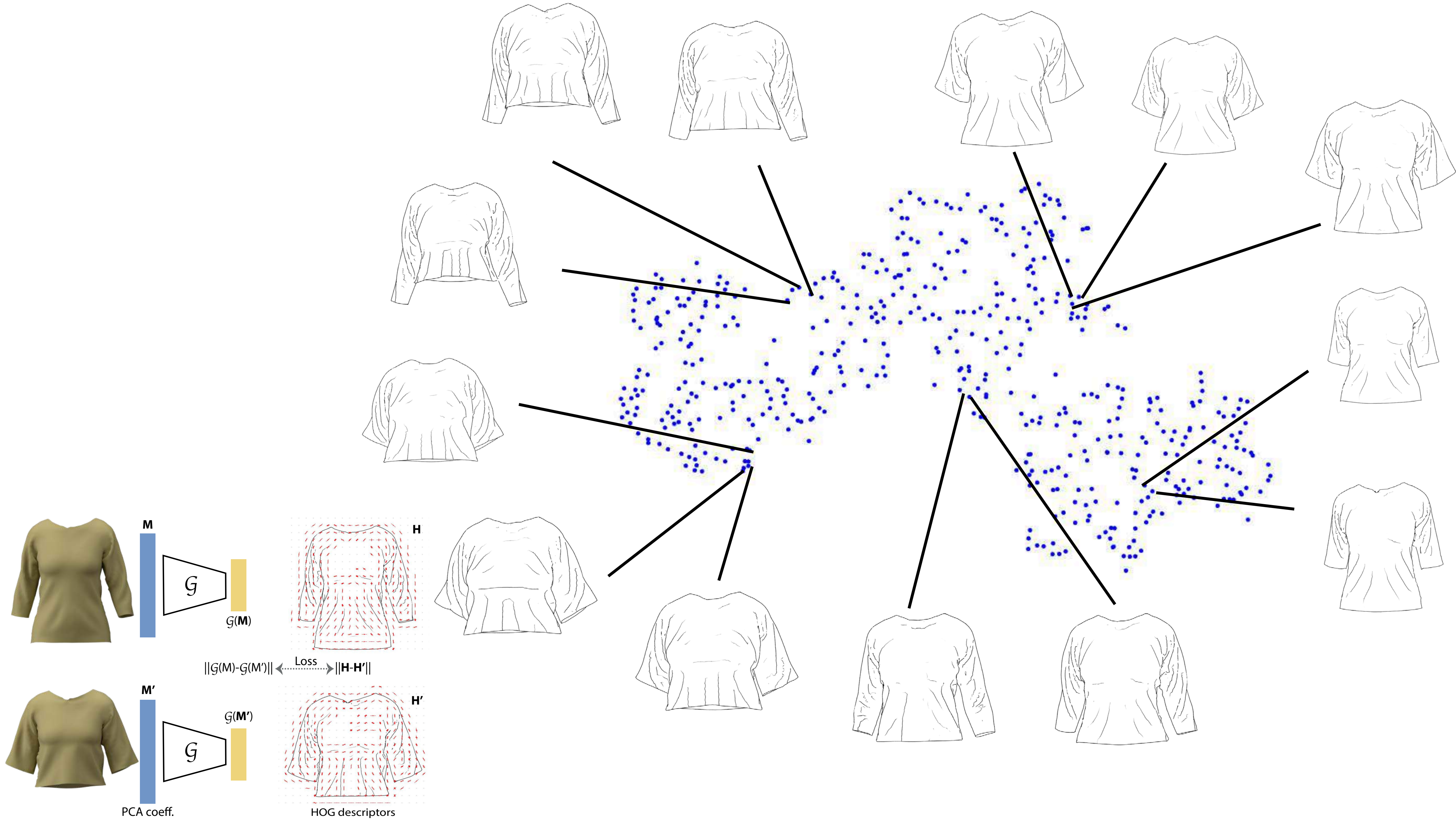
$G(M')$

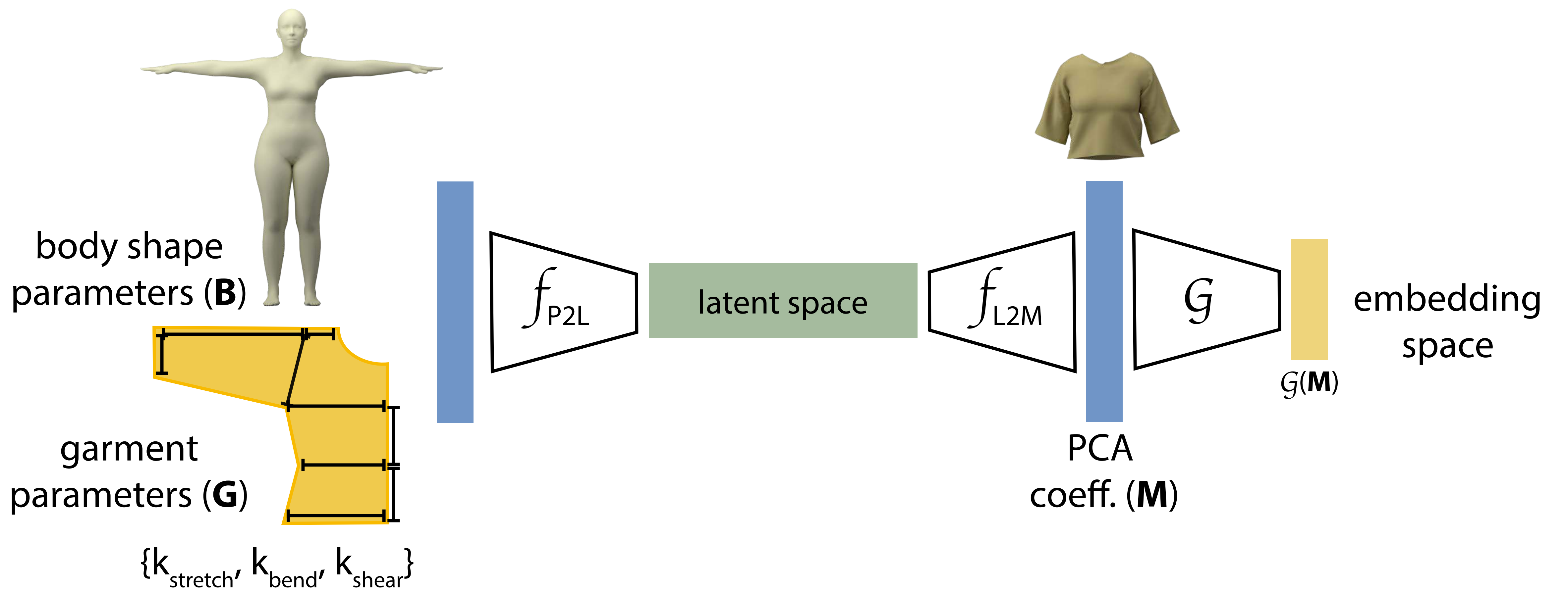


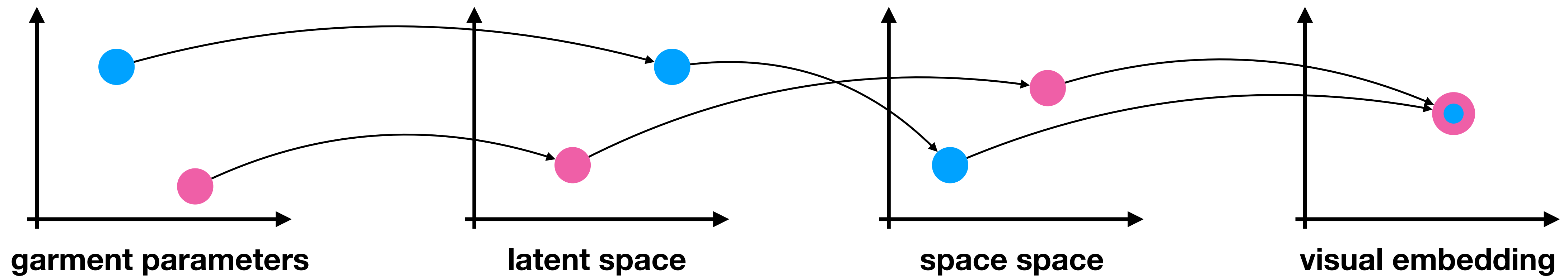
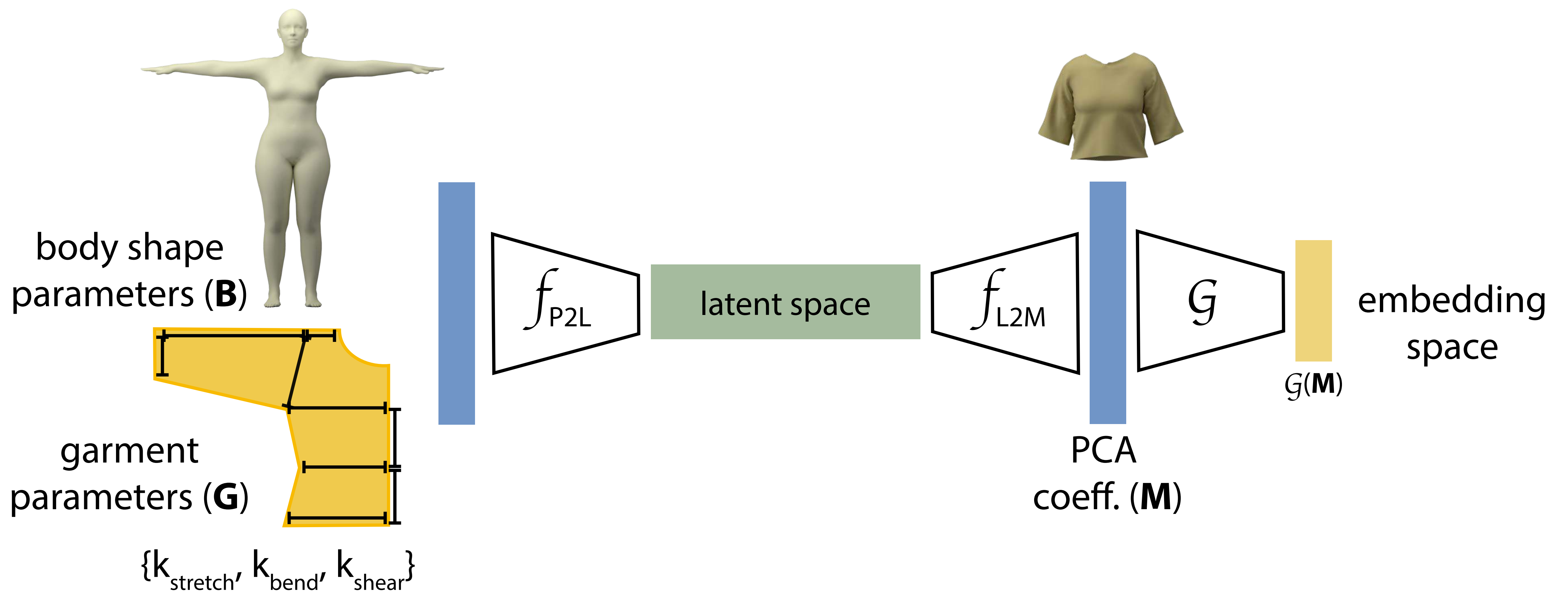
H'

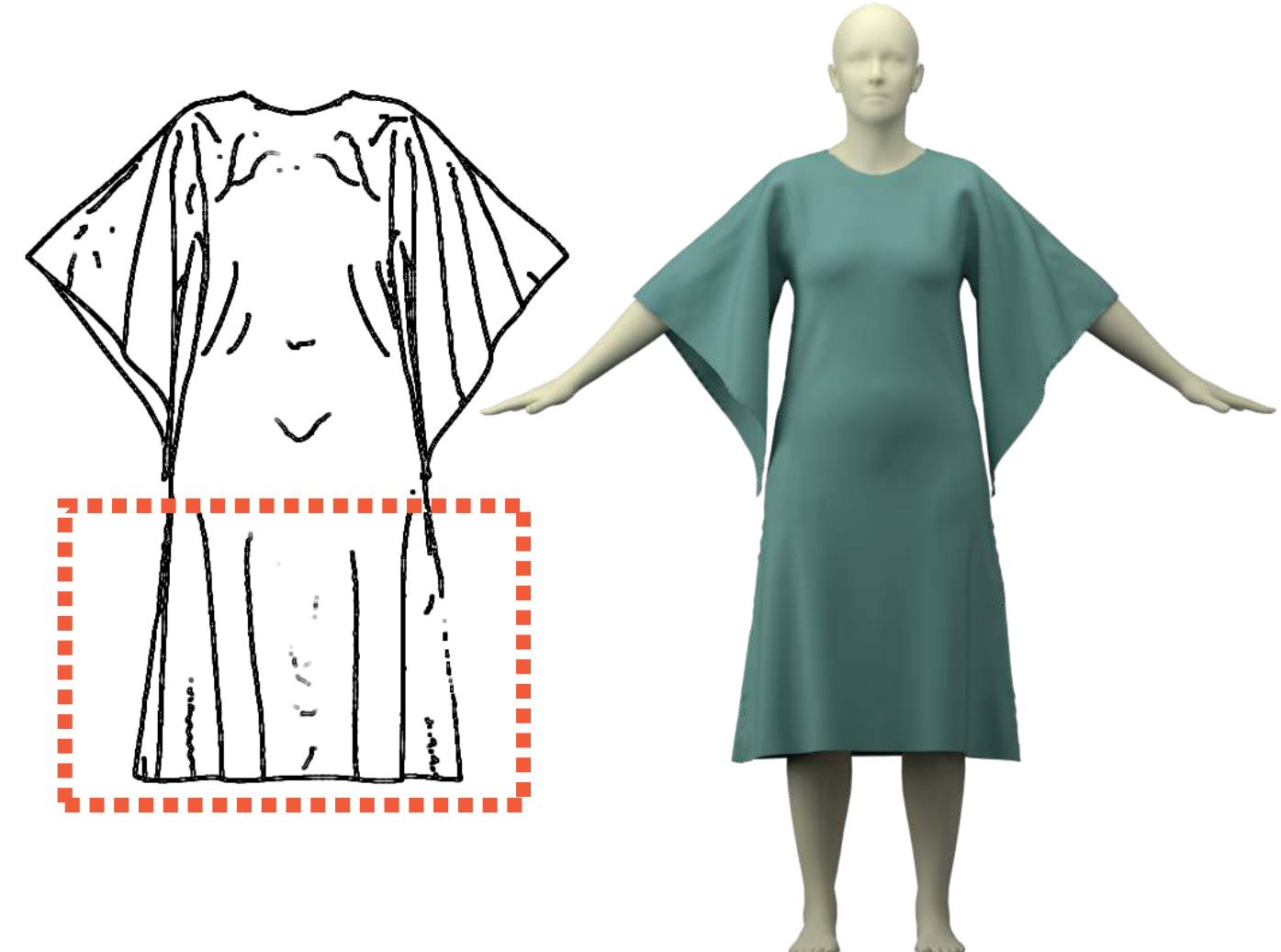
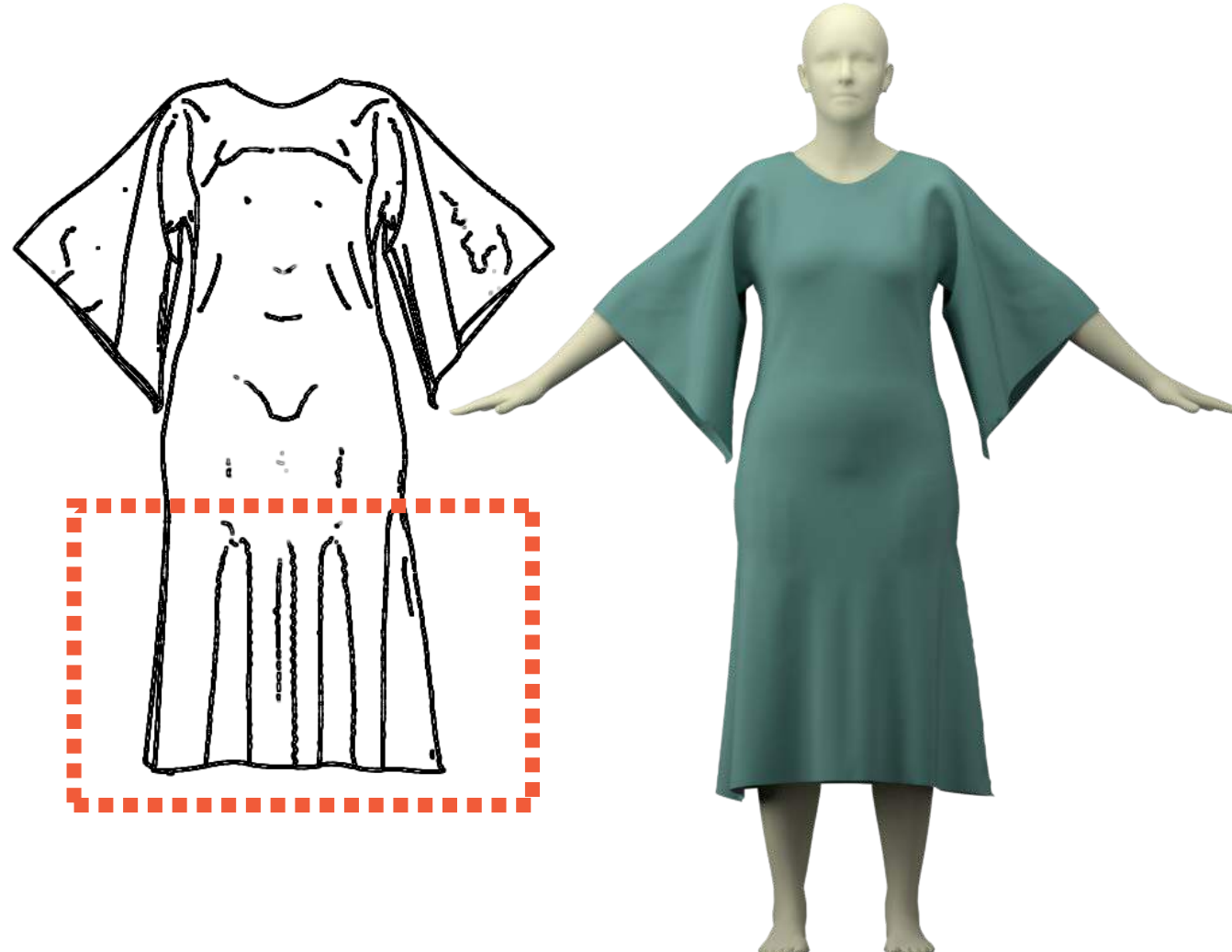
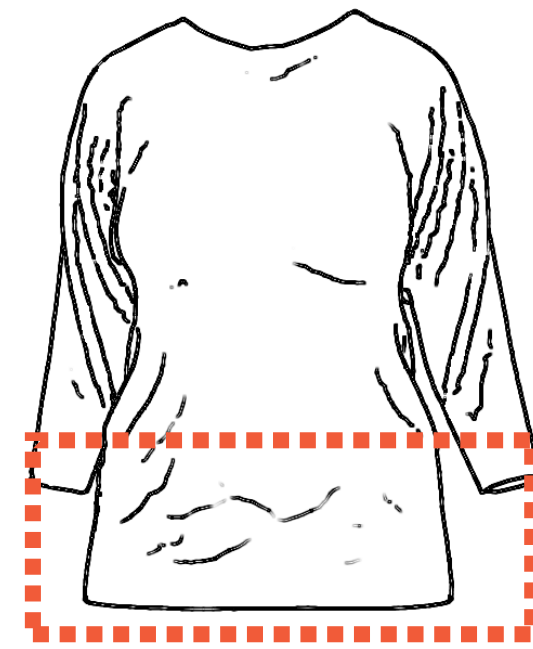
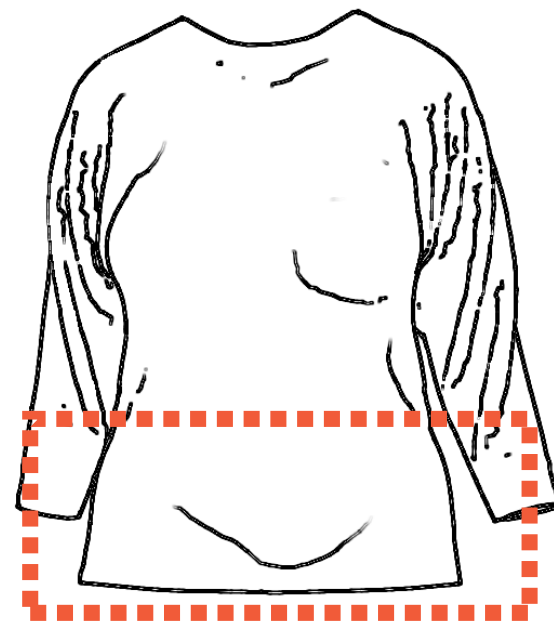
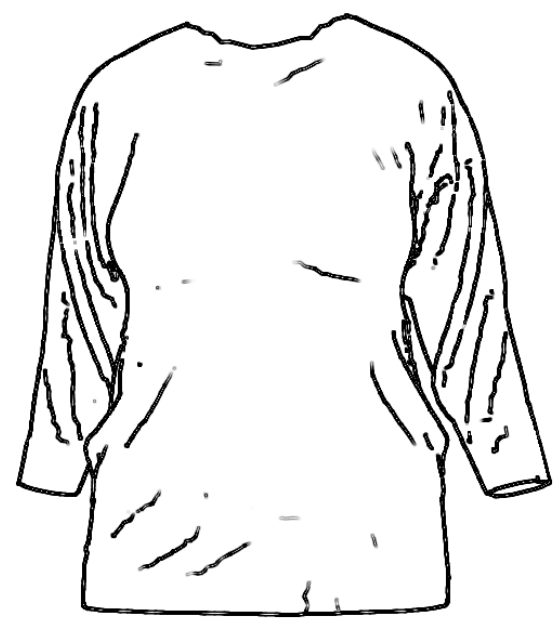
PCA coeff.

HOG descriptors







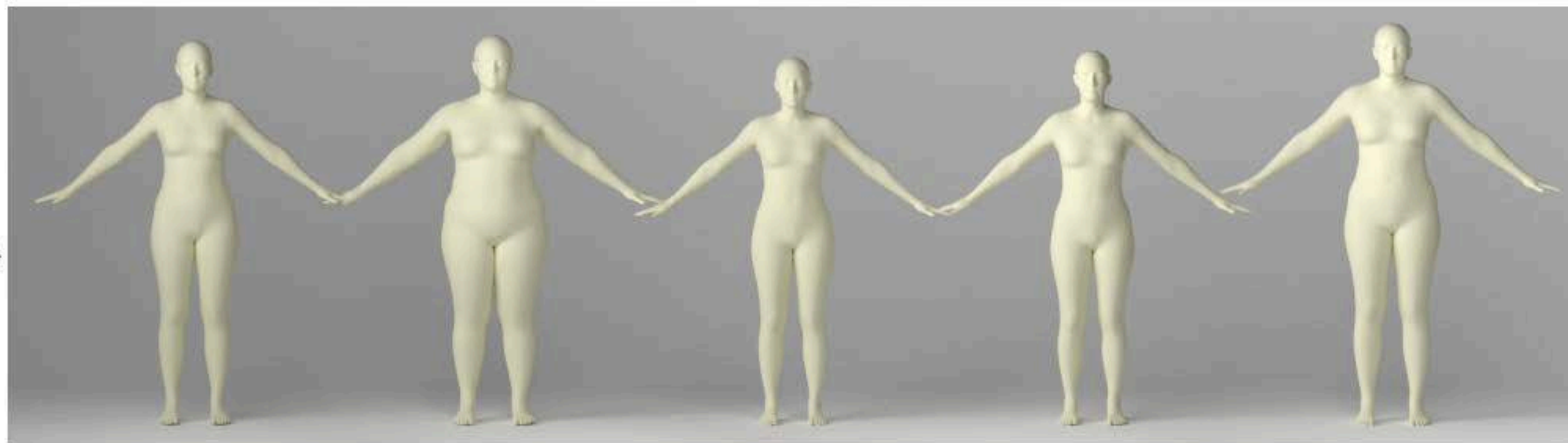


initial garment design (G)
on body (B)

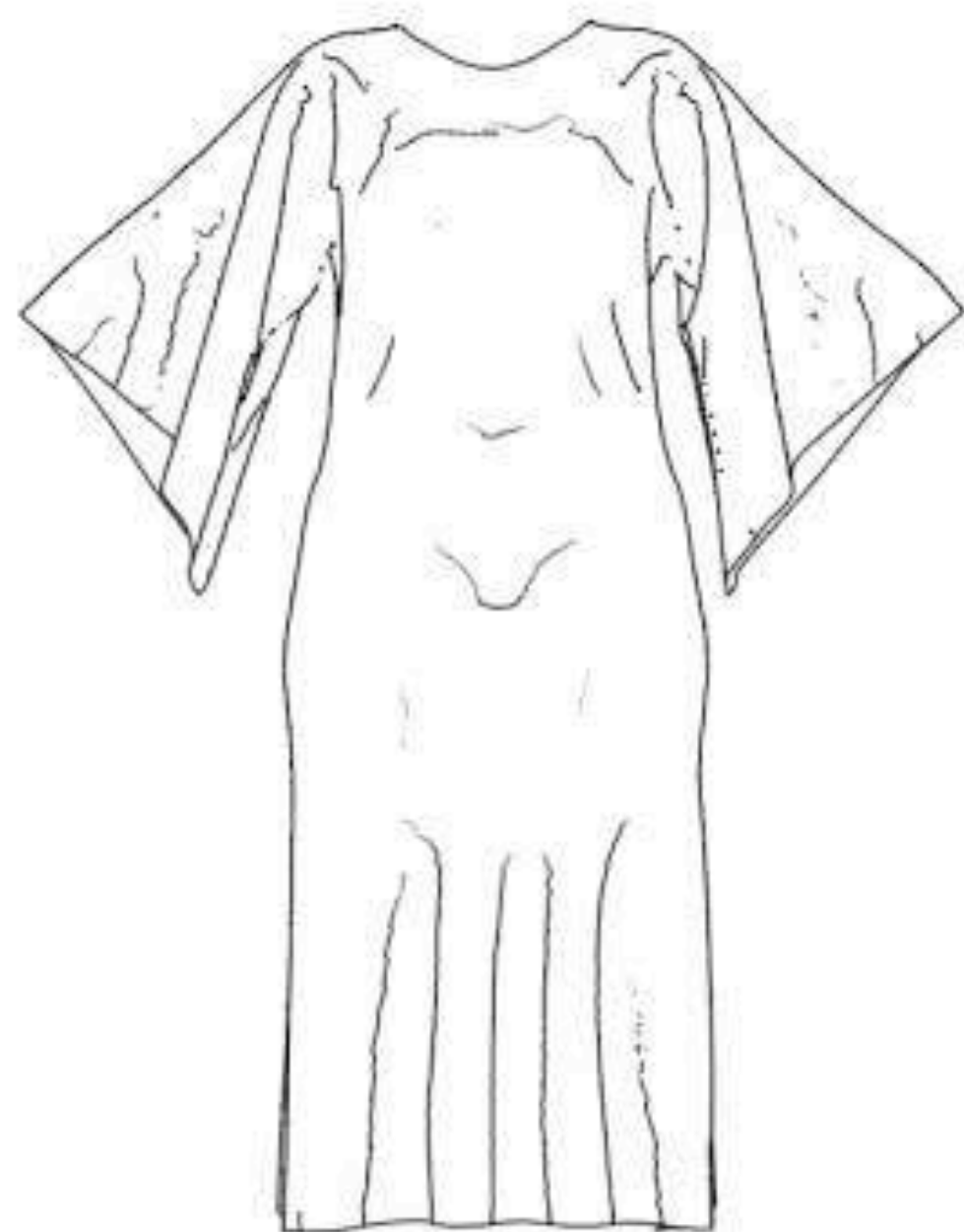
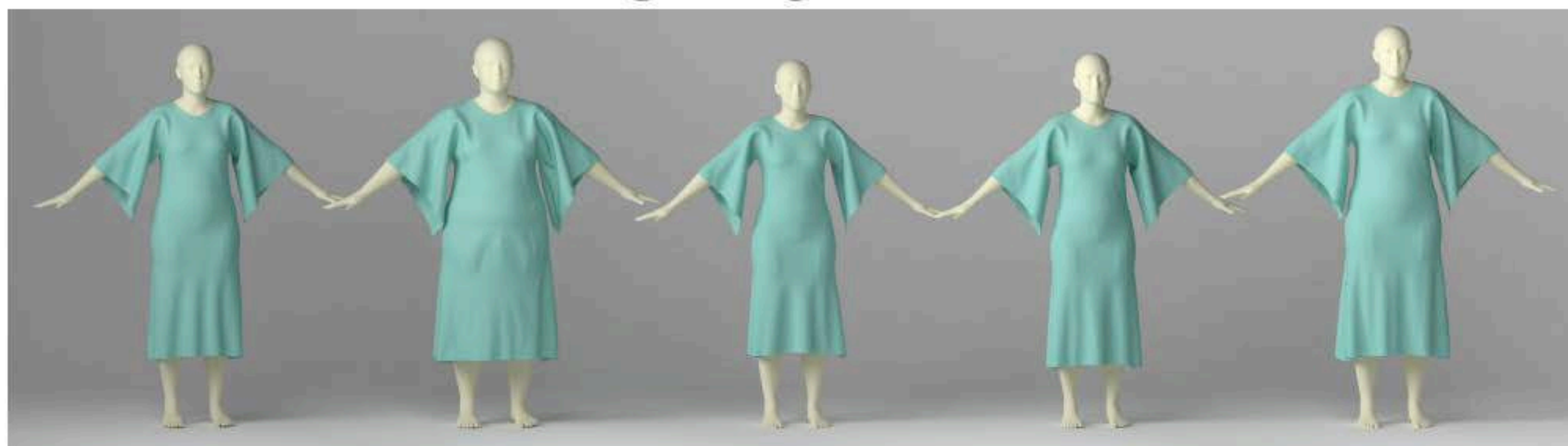
same garment (G) on a
different body (B')

retargetted garment (G')
on body (B')

different body shapes

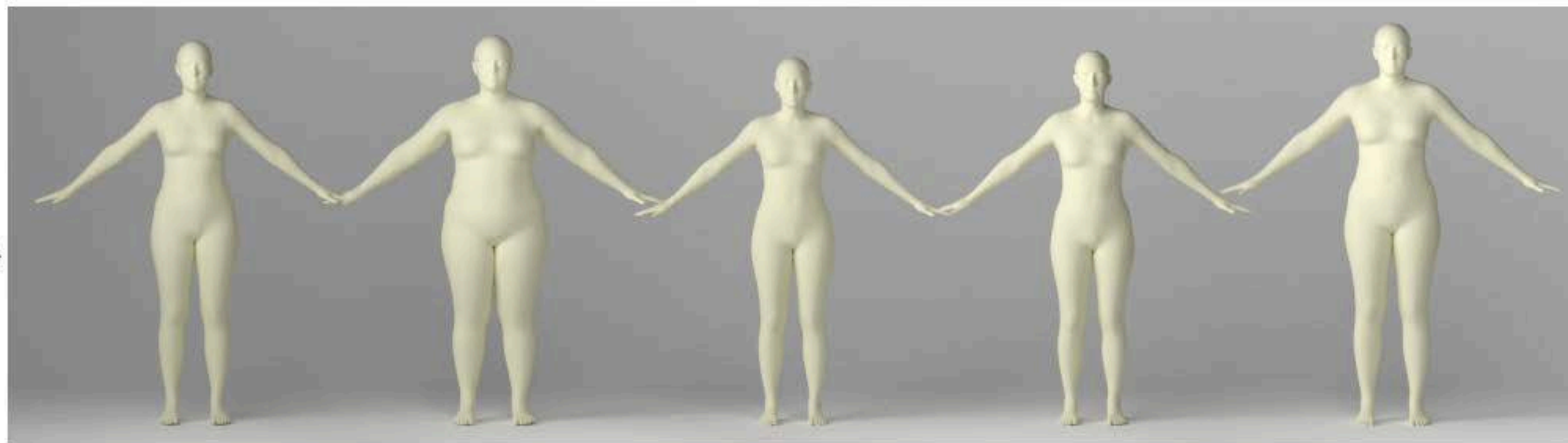


retargeting results

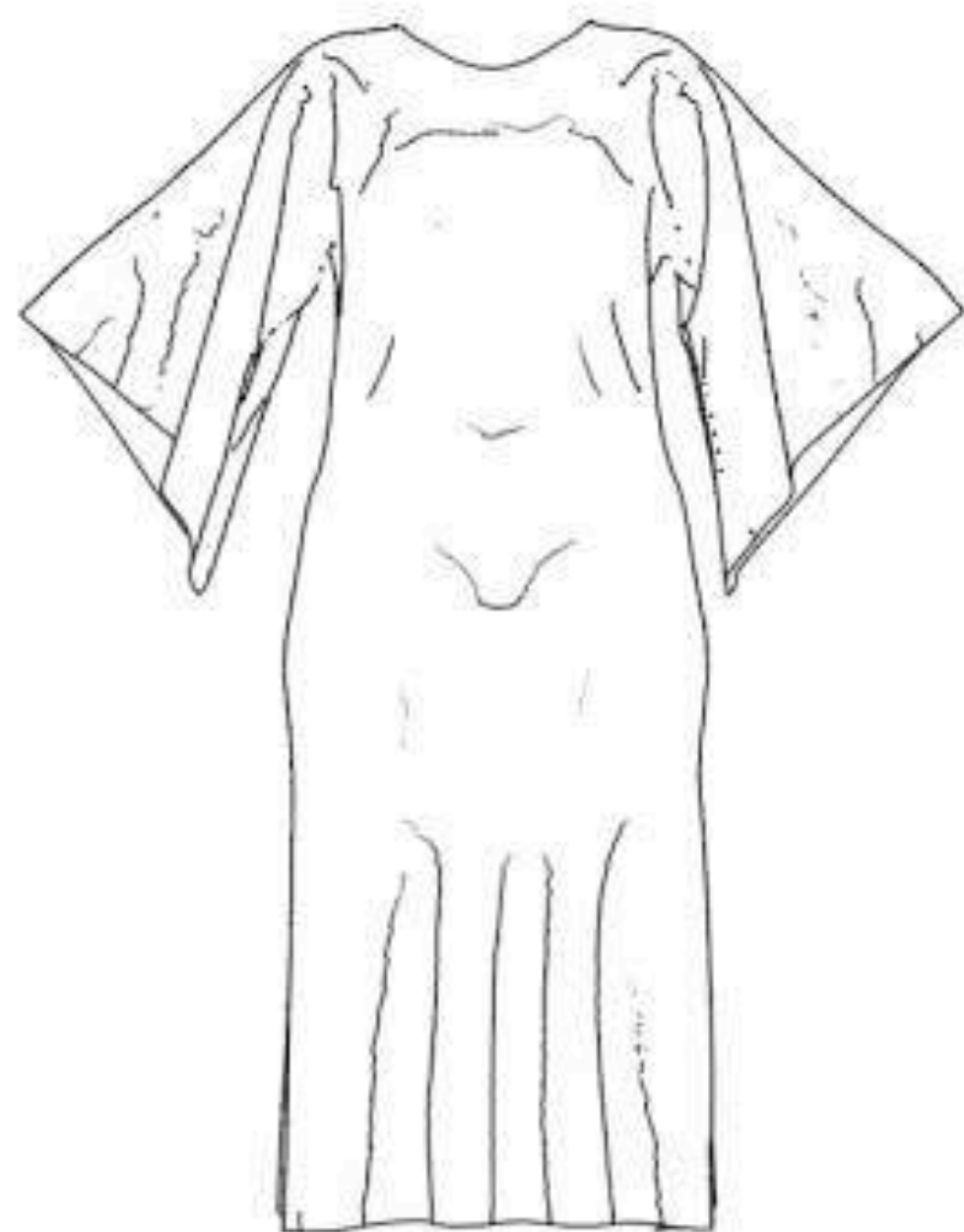
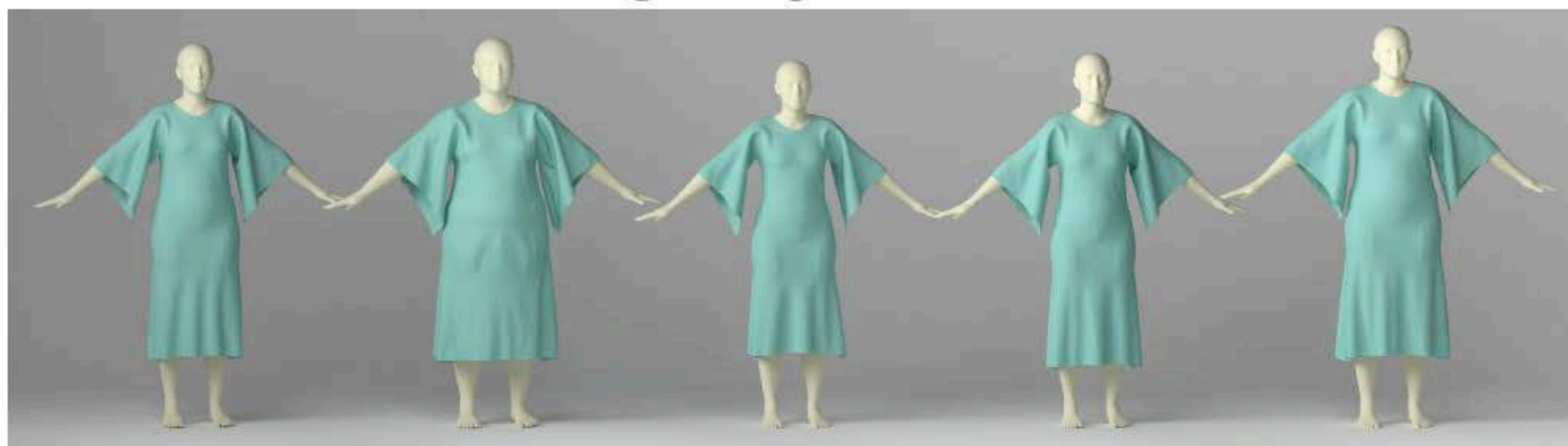


input
sketch

different body shapes

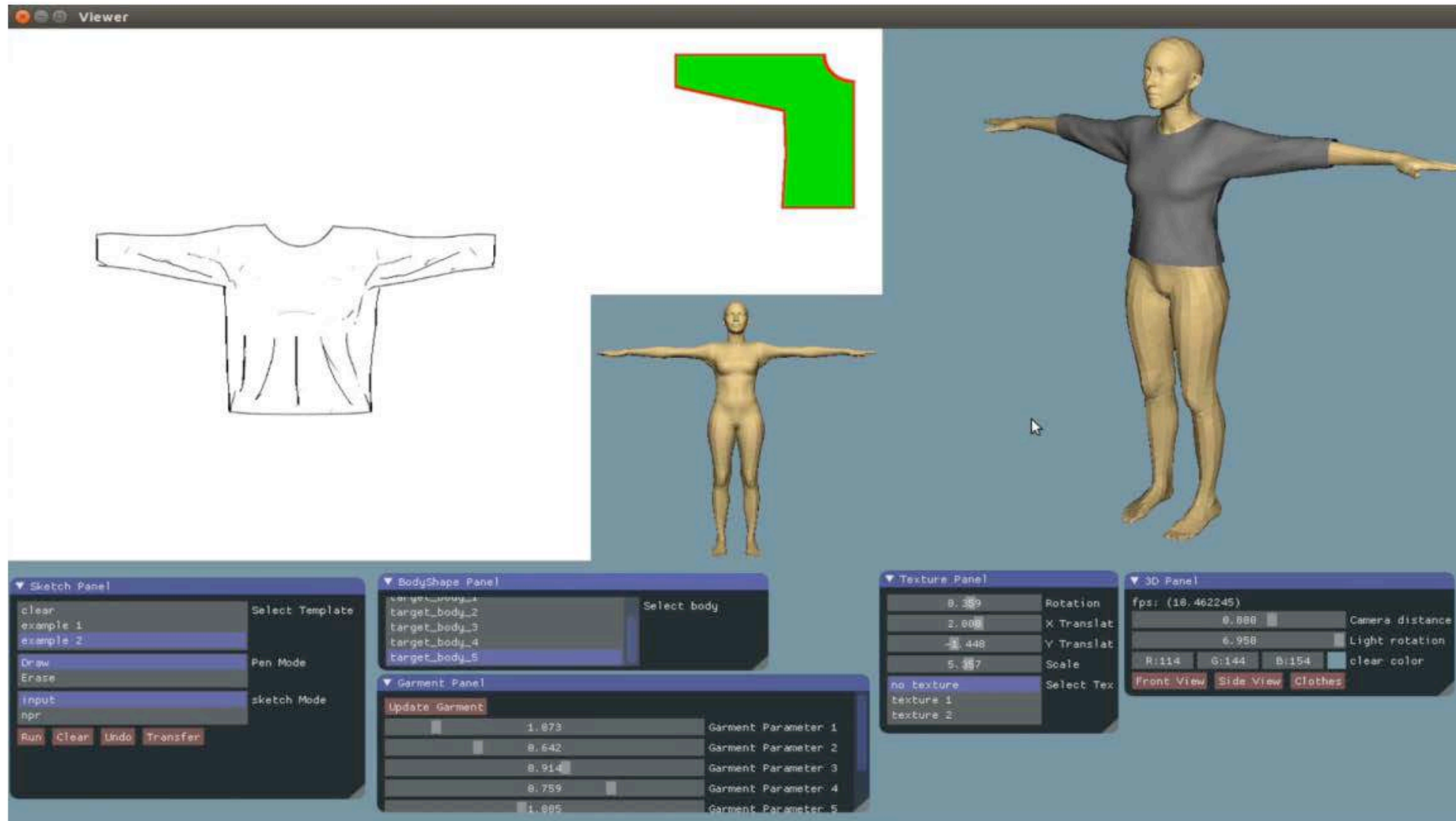


retargeting results

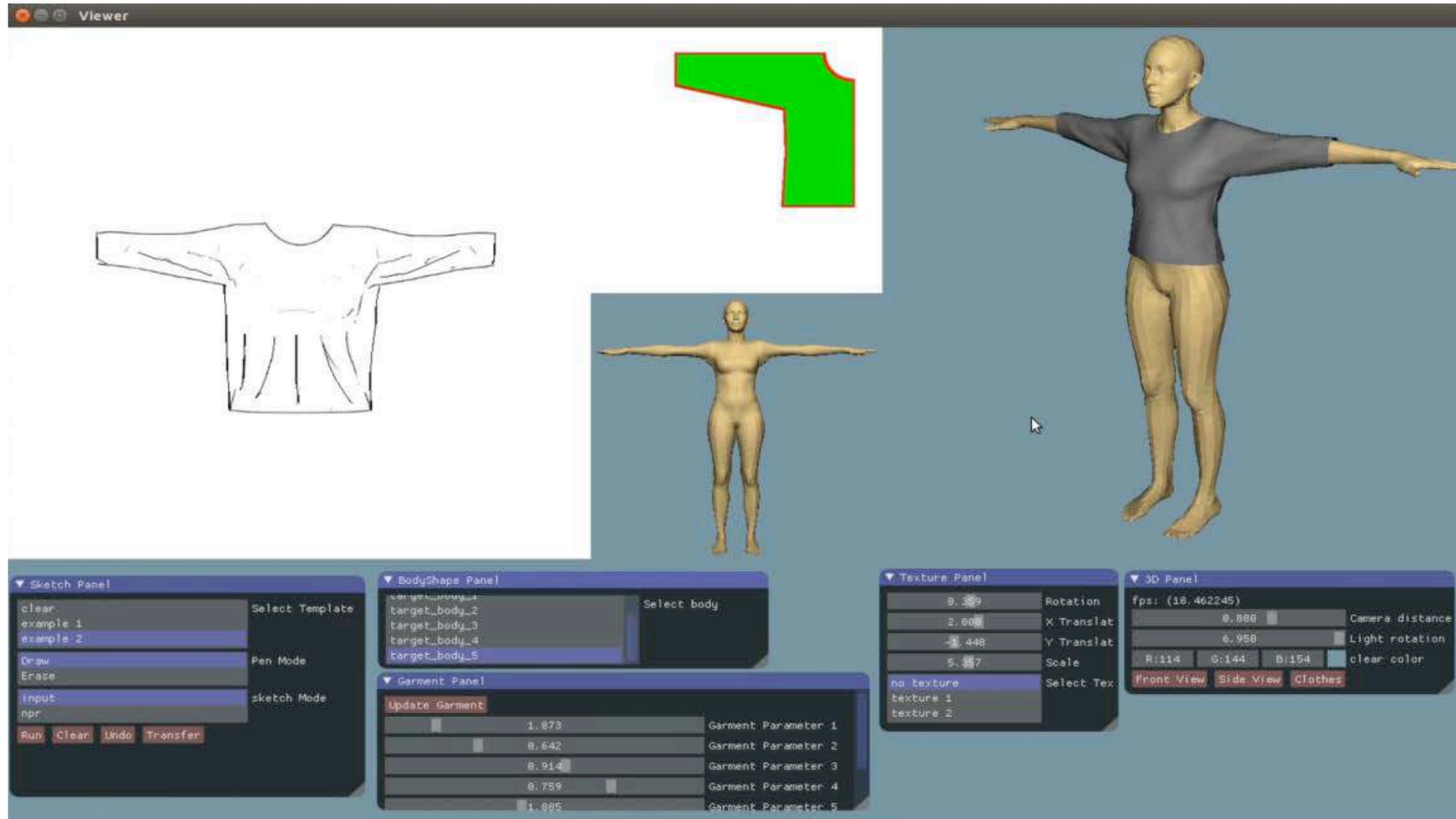


input
sketch

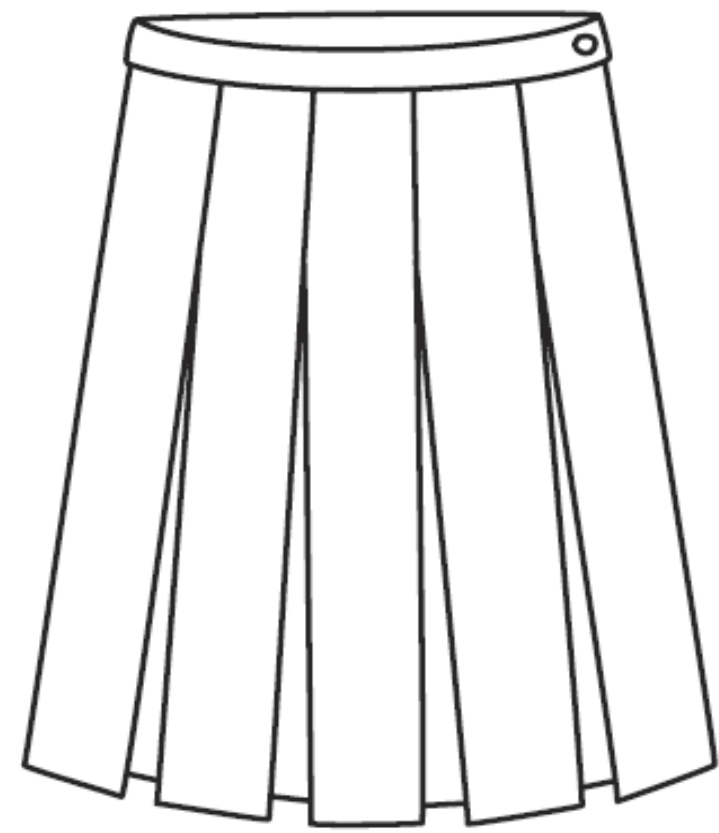
Draping the current garment on different body shapes:



Draping the current garment on different body shapes:



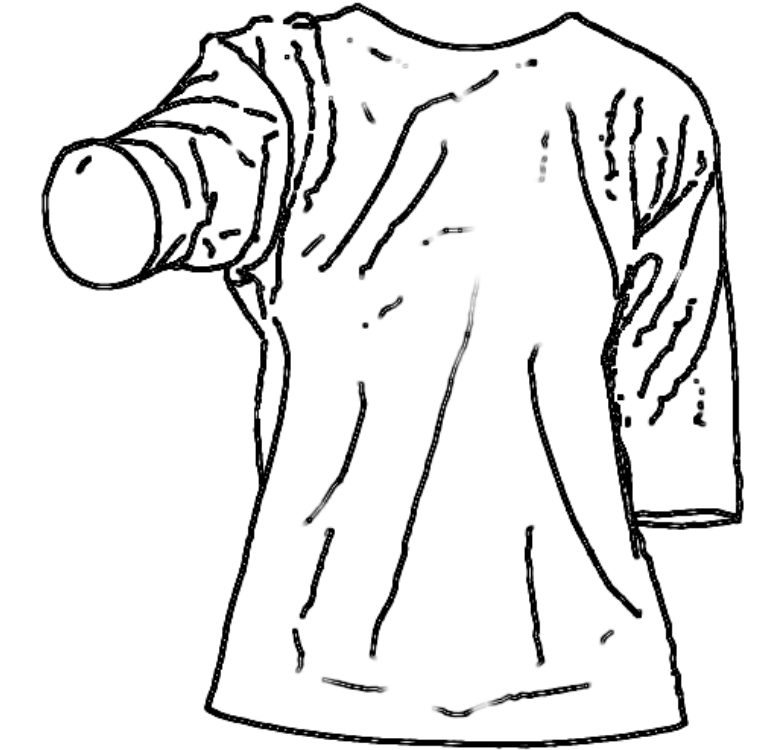
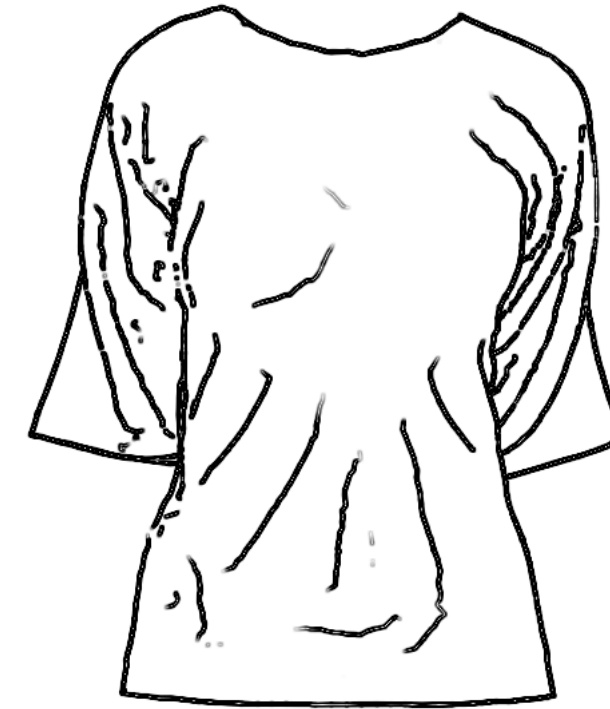
Limitations



A failure case

Future work

input sketch



our result



Background



Tang (Dunhuang), ~ 530 AD



French, 1799



Greece (Parthenon) ~ 400 BC



Tang (Changan), ~ 600 AD

Background



Tang (Dunhuang), ~ 530 AD



French, 1799



Greece (Parthenon) ~ 400 BC



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Tang (Dunhuang), ~ 530 AD



French, 1799



Greece (Parthenon) ~ 400 BC



Tang (Changan), ~ 600 AD

Background



Disney, 1937



Toei Animation, 1990



Illumination Entertainment, 2010

Background



Disney, 1937



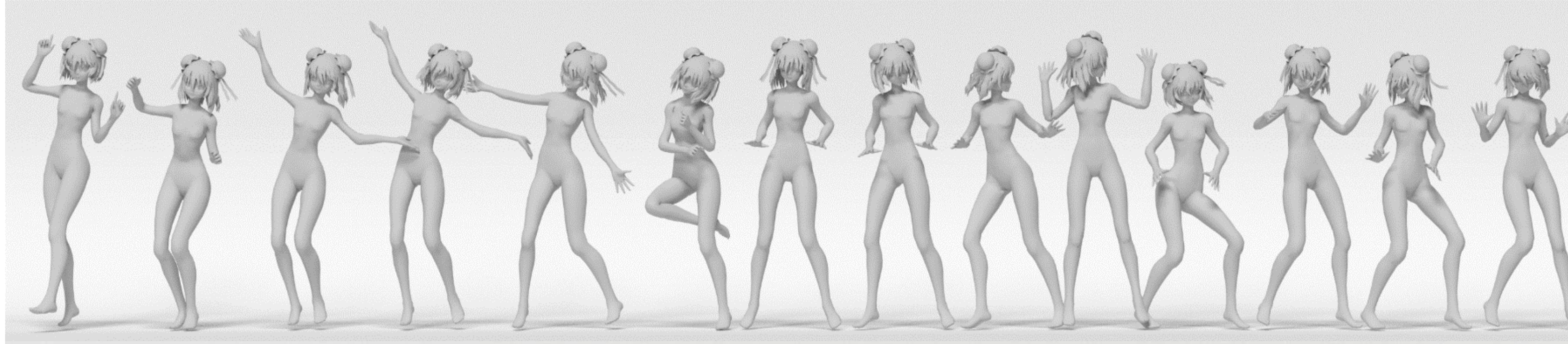
Toei Animation, 1990



Illumination Entertainment, 2010

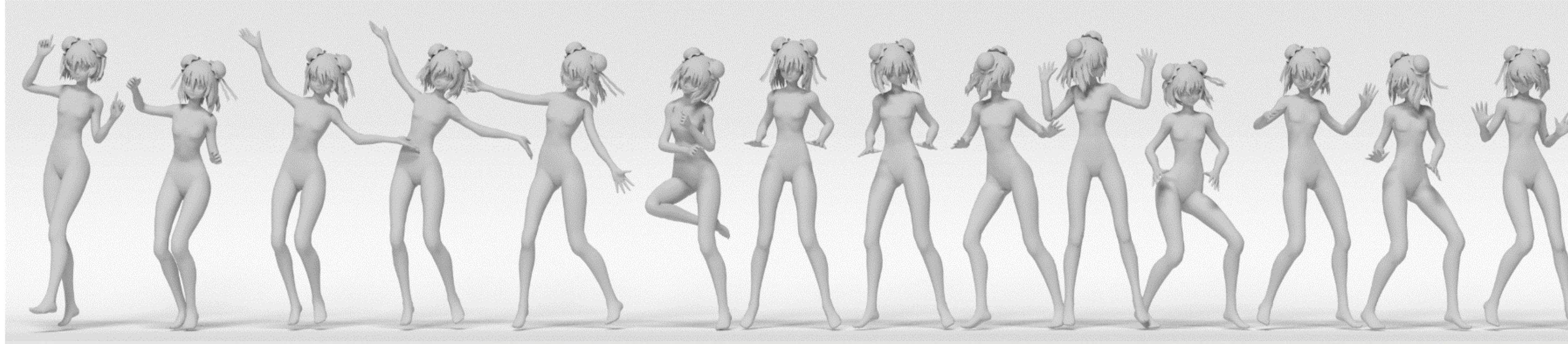
Problem formulation

Character Motion



Problem formulation

Character Motion



Garment Animation



A possible approach: physically based simulation

[Tang et al. 2018]



+) Automatic

-) Lots of parameters

- Hard to tune as a combination
- Some parameters lack physical meaning
- Global parameter set may not exist
- Parameters interpolation leads to unexpected shape change

-) Difficult to apply shape constrains (keyframe control)

A possible approach: physically based simulation

[Tang et al. 2018]



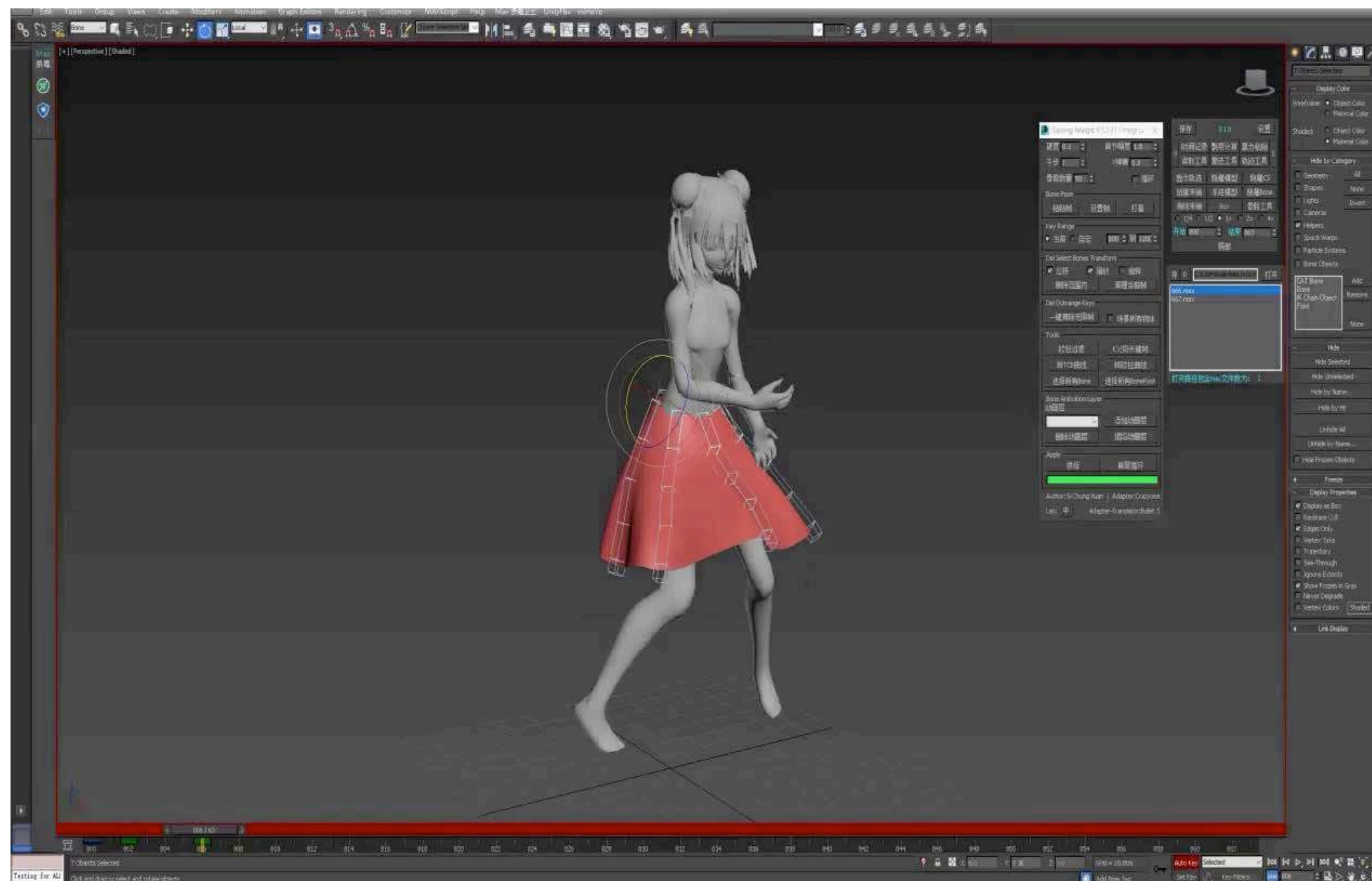
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Current workflow: keyframes + interpolation

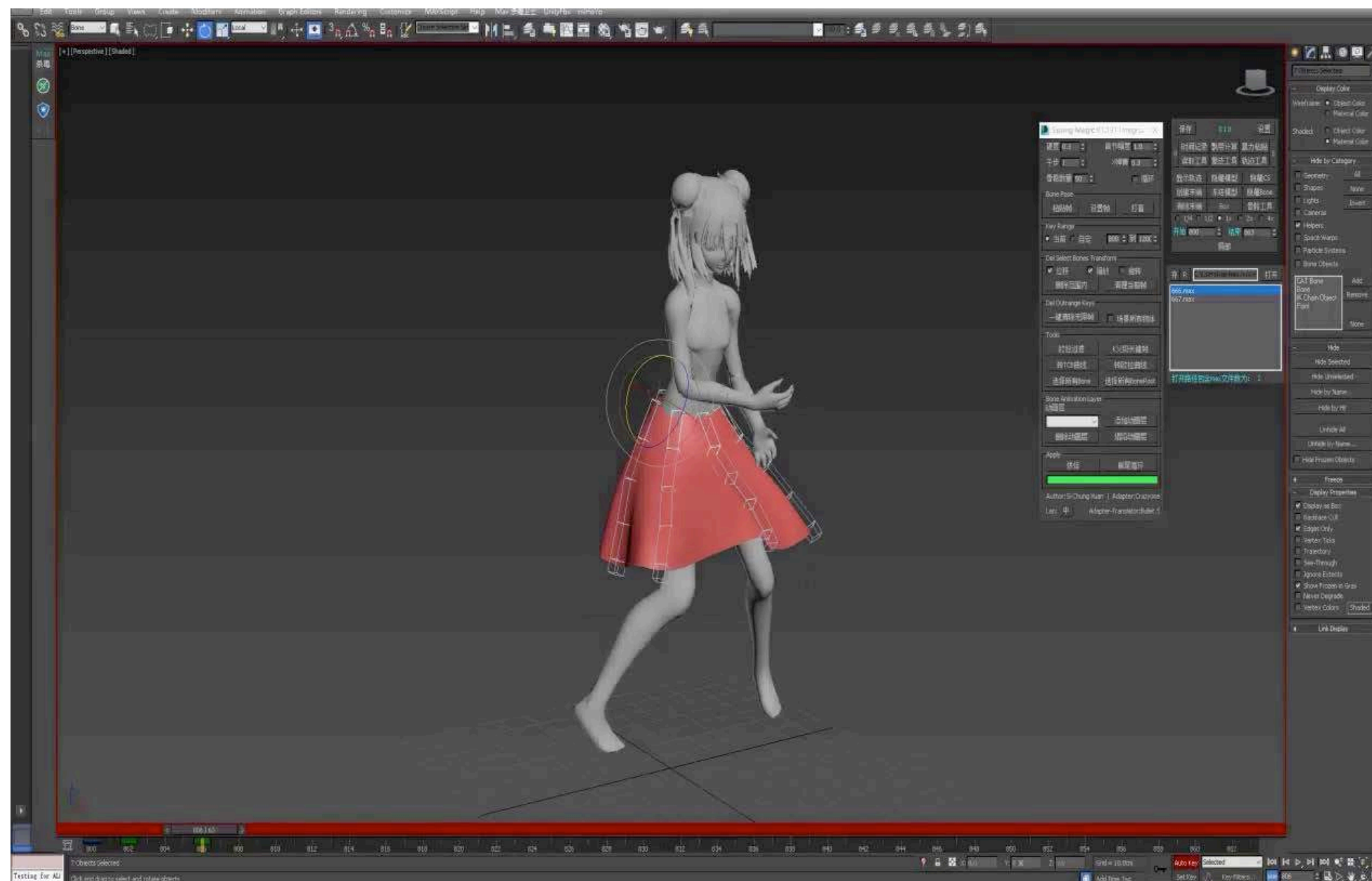


+ full control

- editing a keyframe is labor-consuming

- dense keyframe

Current workflow: keyframes + interpolation



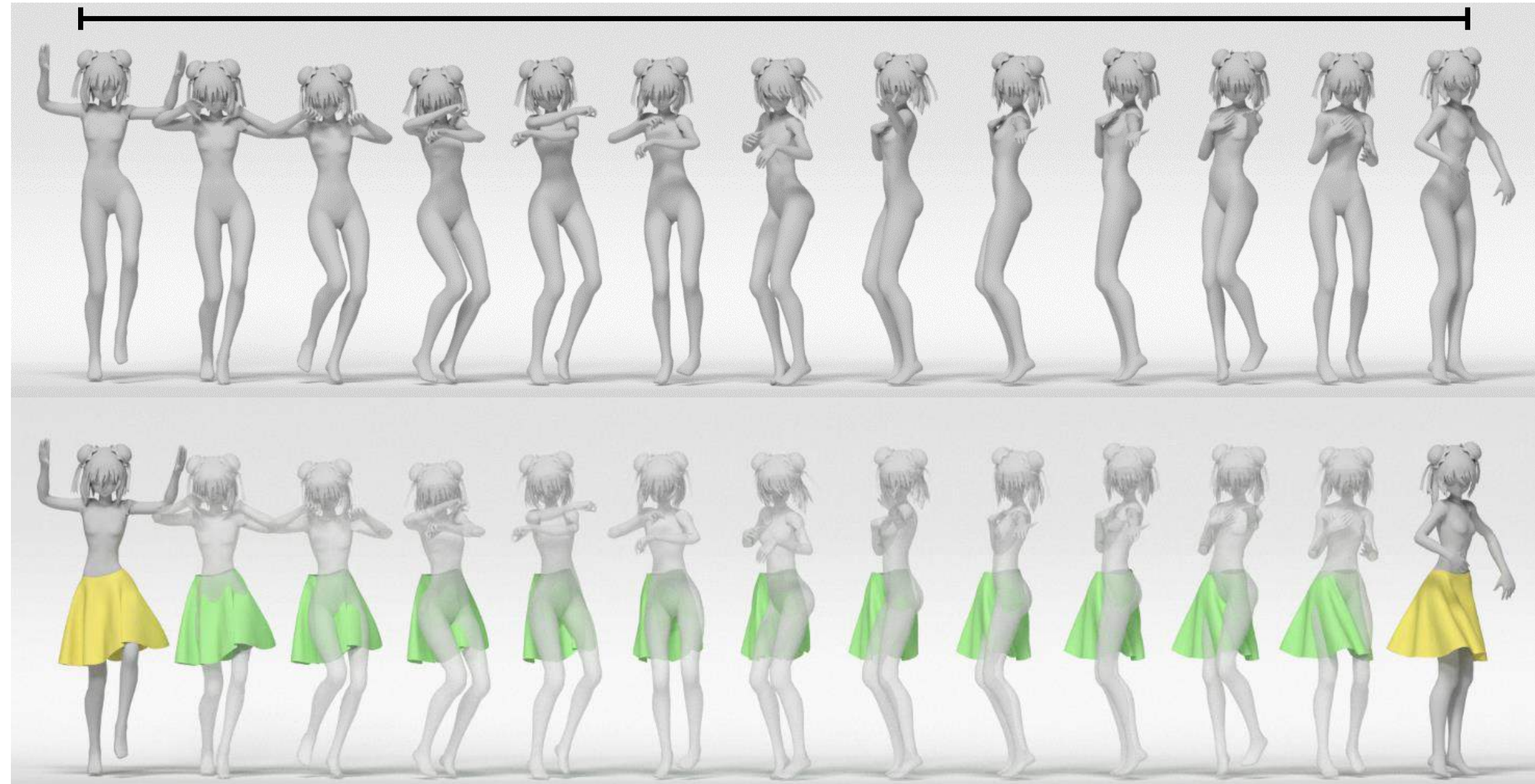
+ full control

- editing a keyframe is labor-consuming

- dense keyframe

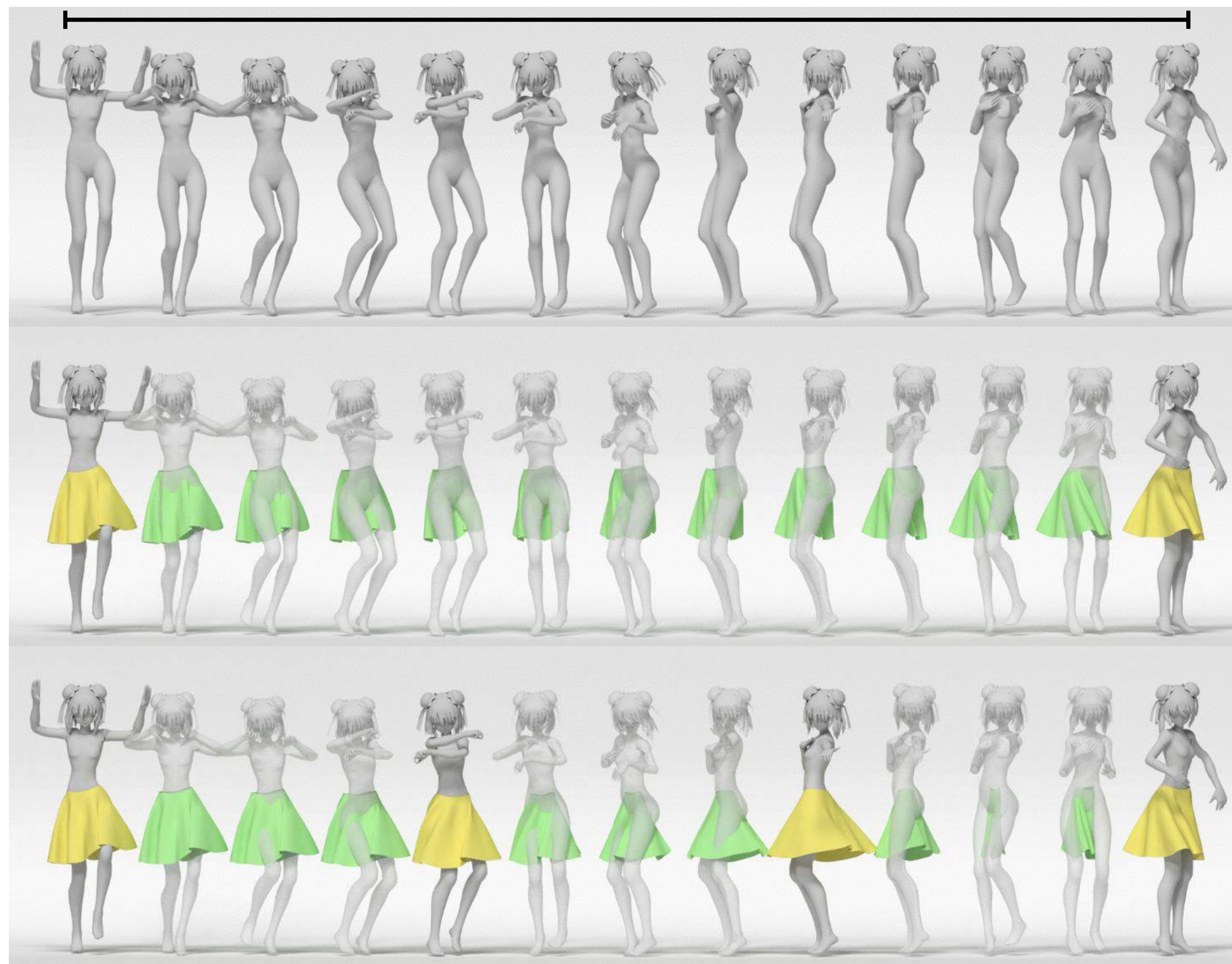
Motivation

36 frames \approx 1.5s



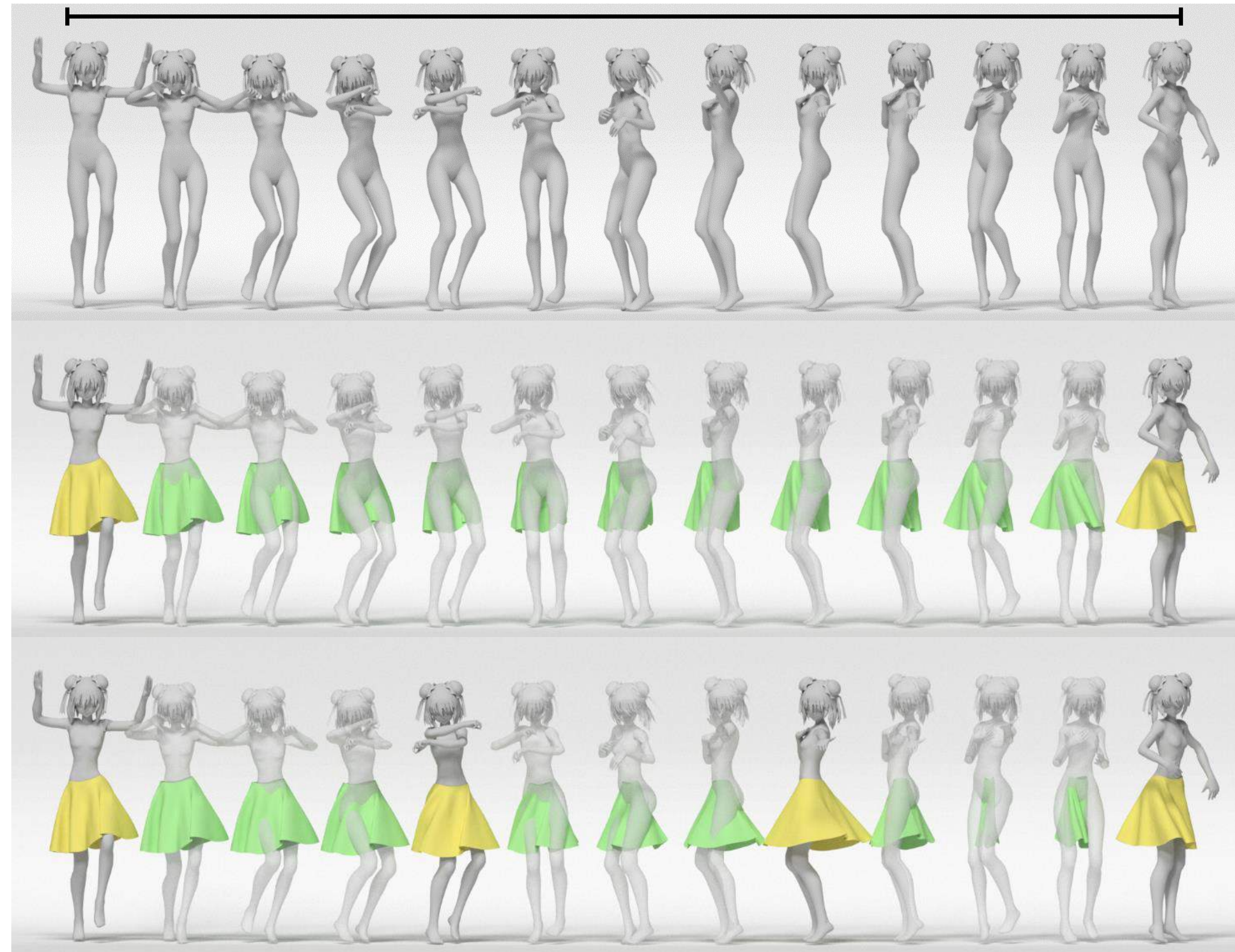
Motivation

36 frames \approx 1.5s



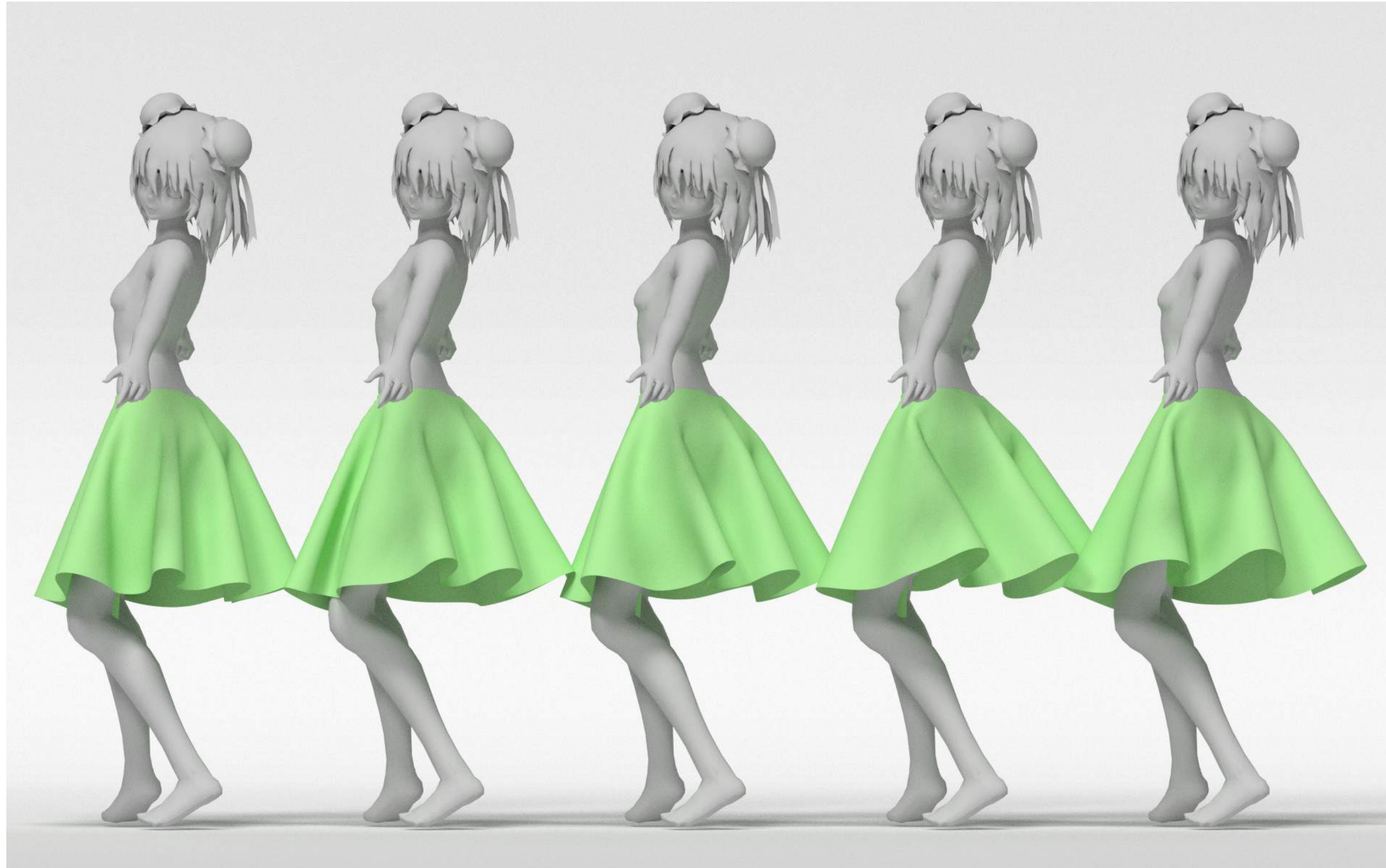
Motivation

36 frames \approx 1.5s



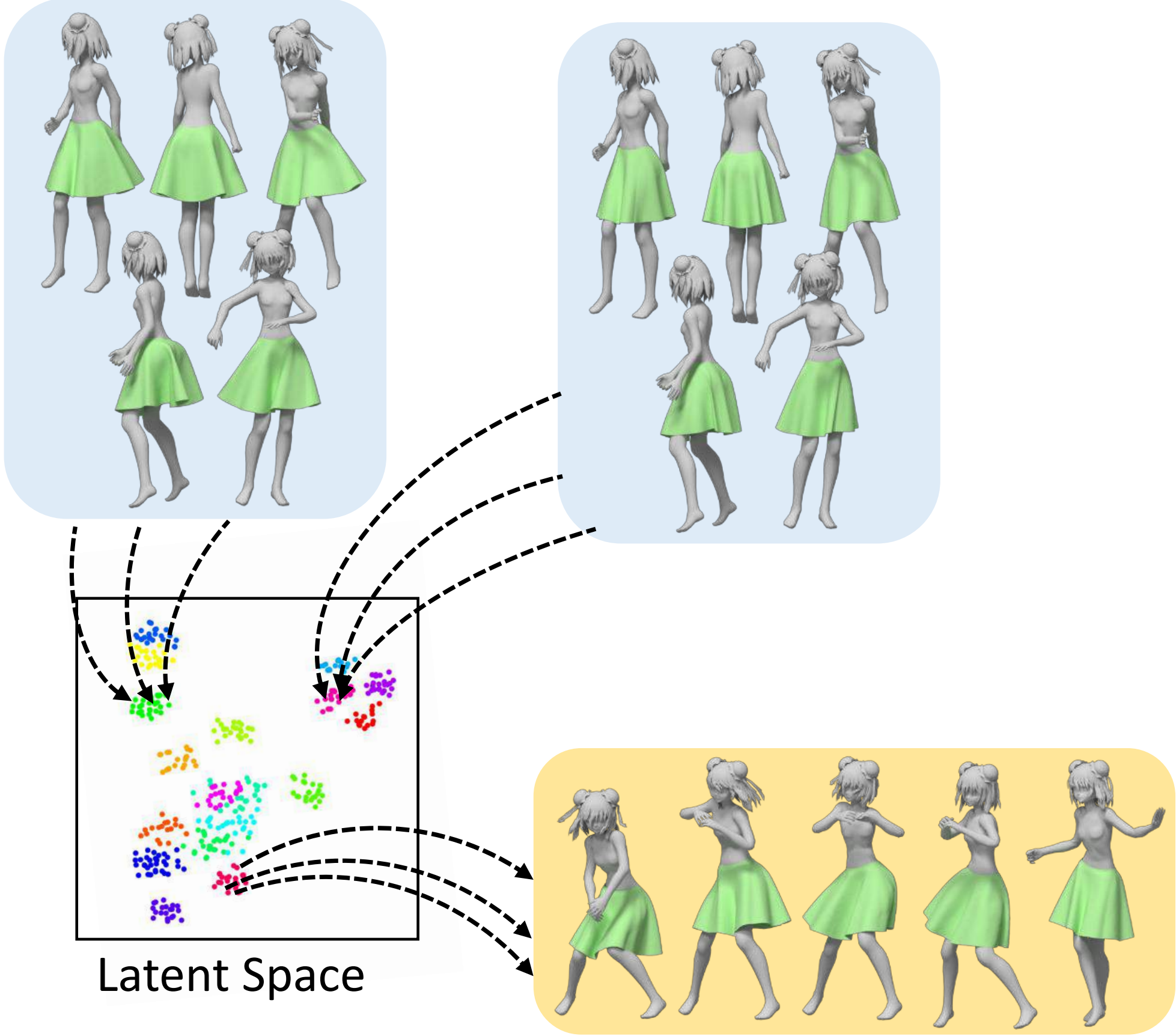
Can we use fewer
keyframes?

Key observation

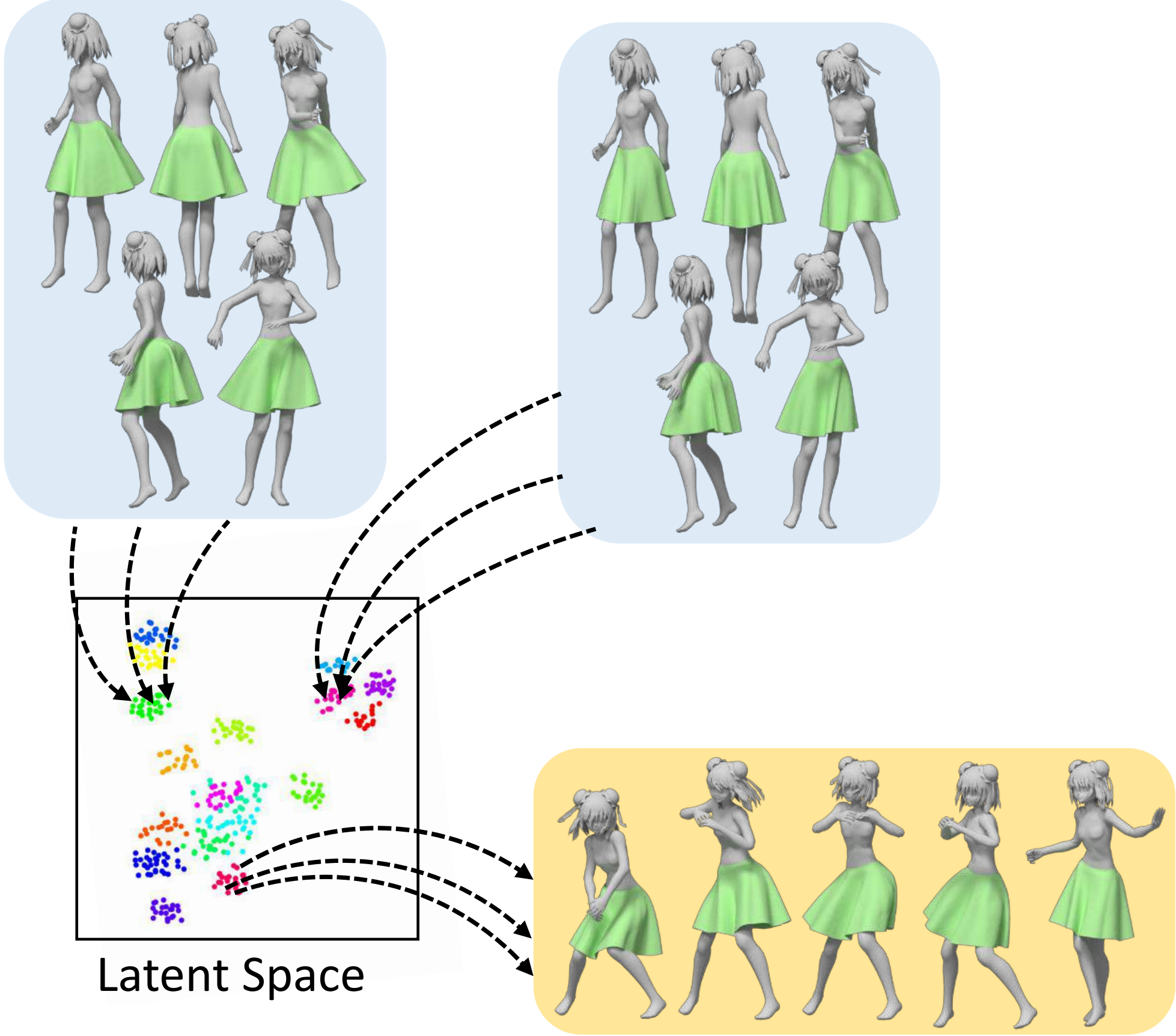


What can be changed in a certain keyframe?

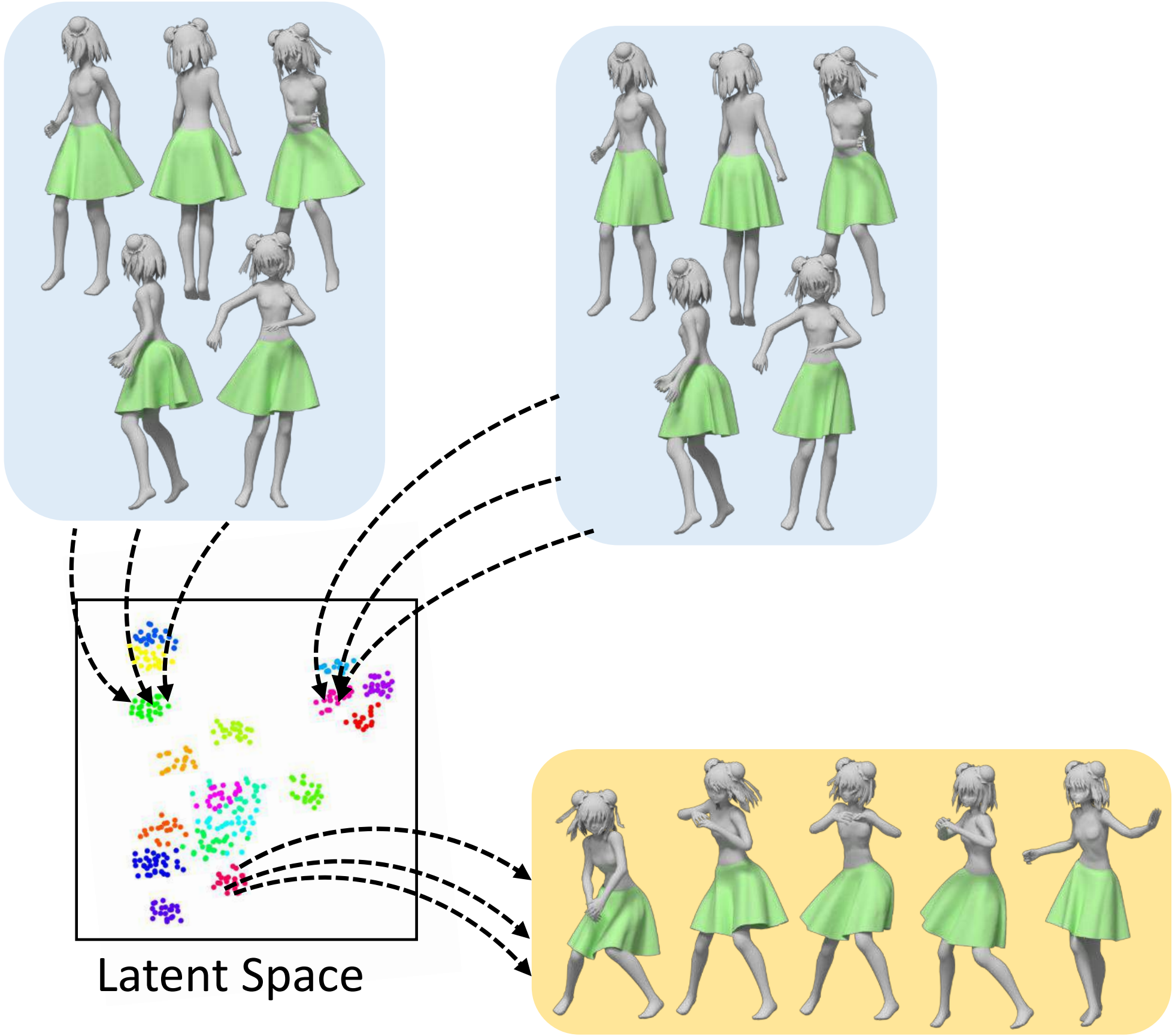
Solution: factor out character motion and motion independent parameters

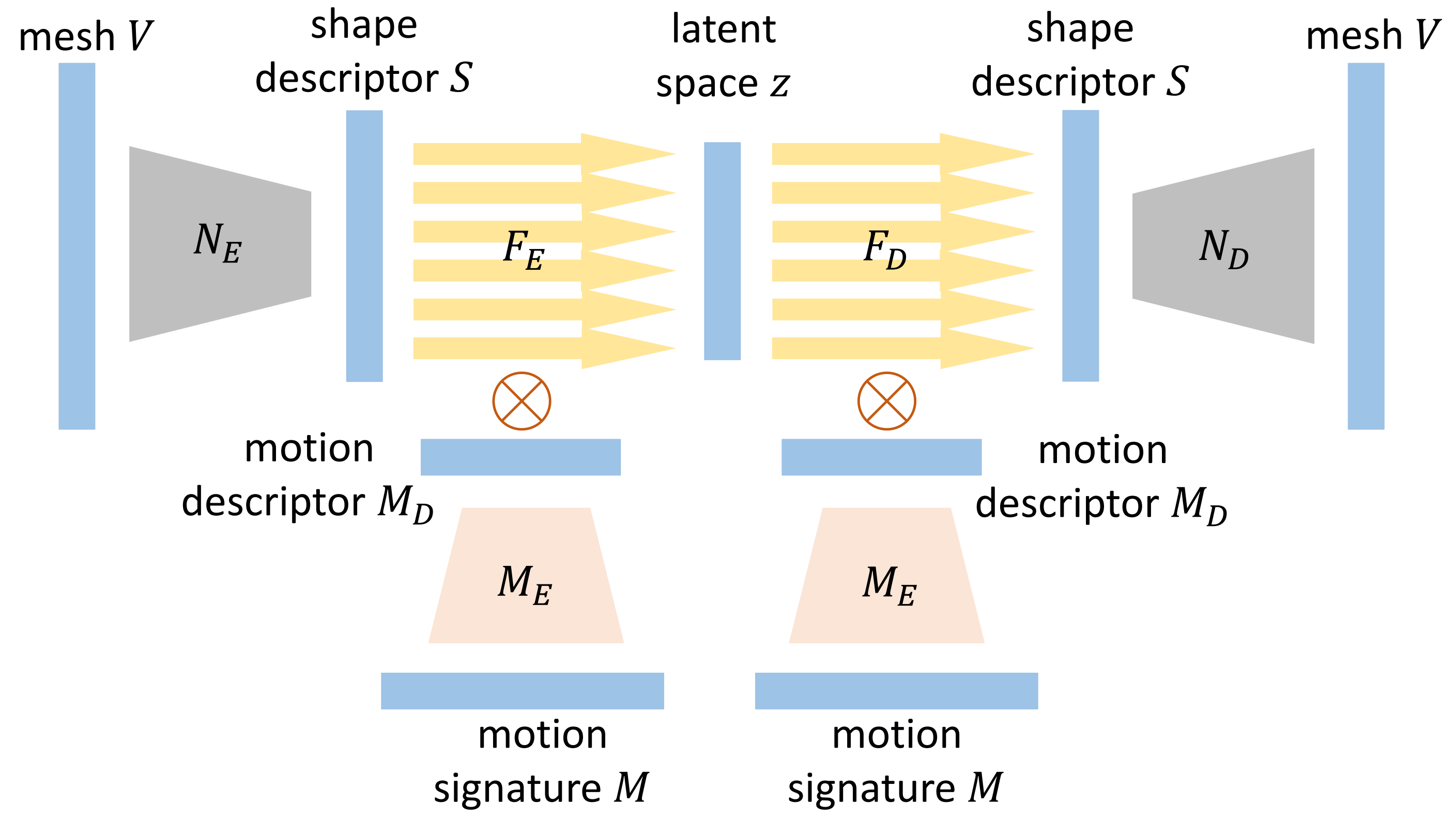


Solution: factor out character motion and motion independent parameters



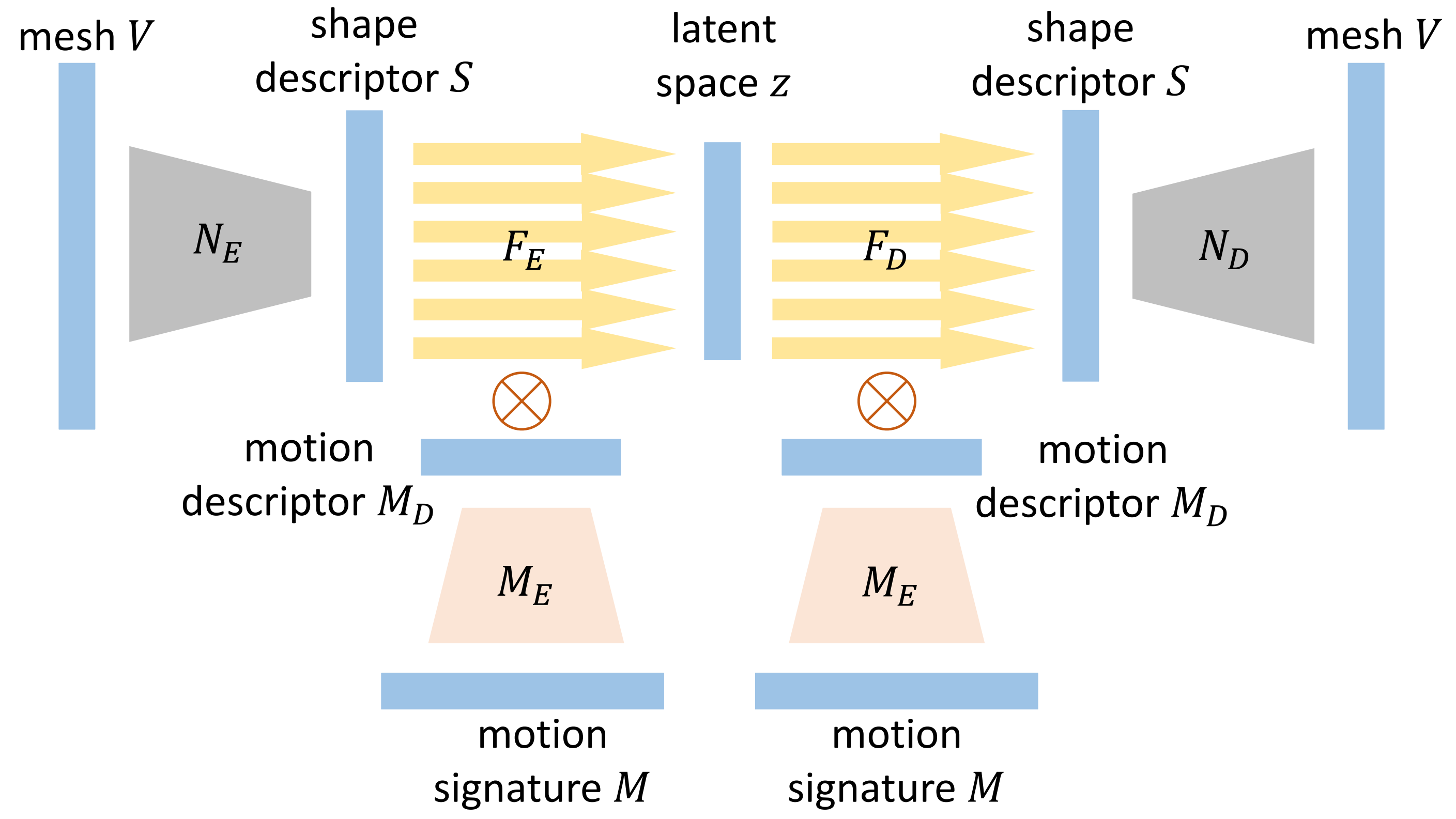
Solution: factor out character motion and motion independent parameters





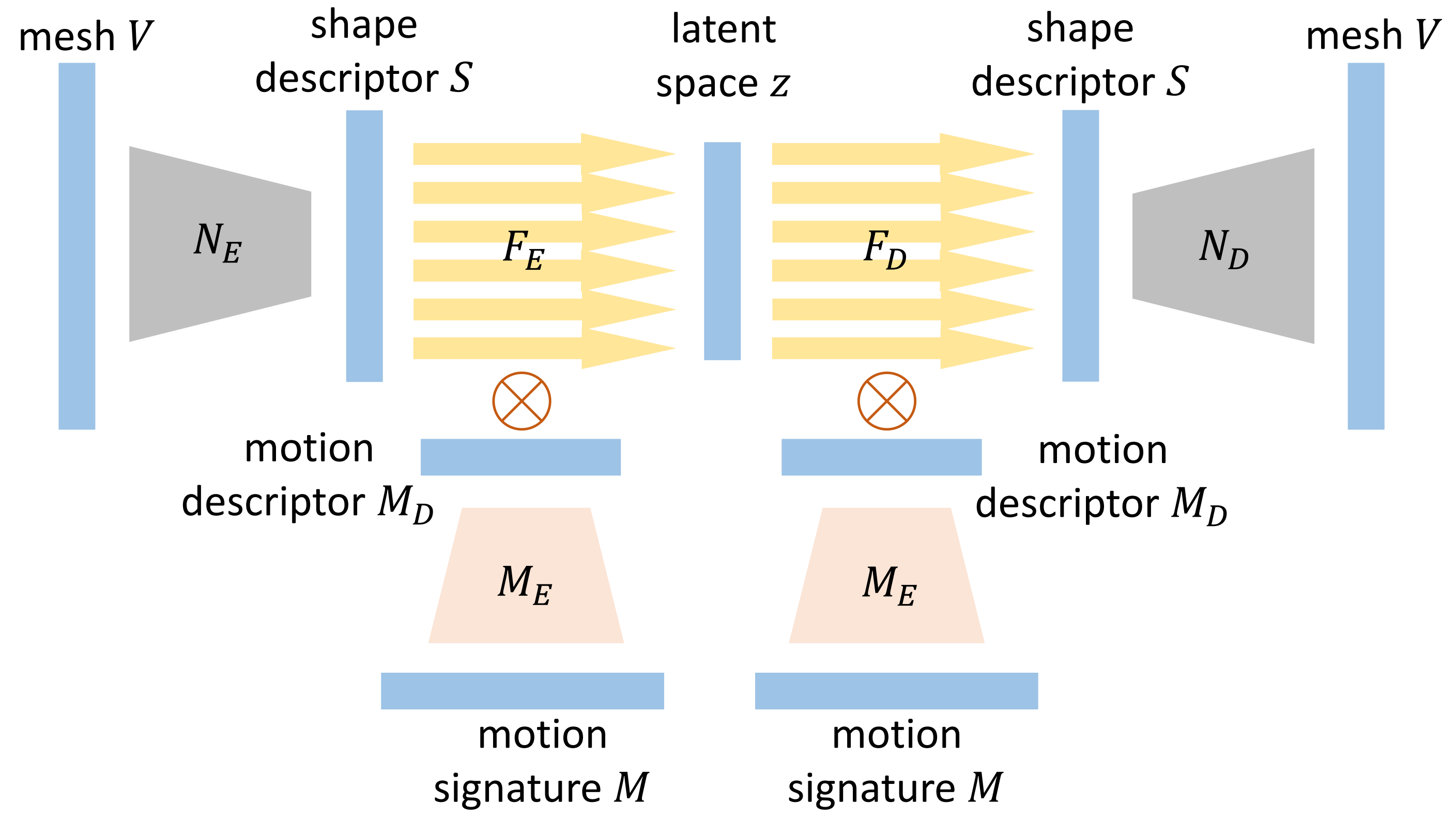
For a batch generated with the same parameters:

$$E = \mathbf{Var}(z) + \lambda \cdot \|S_i - S_i^*\|$$



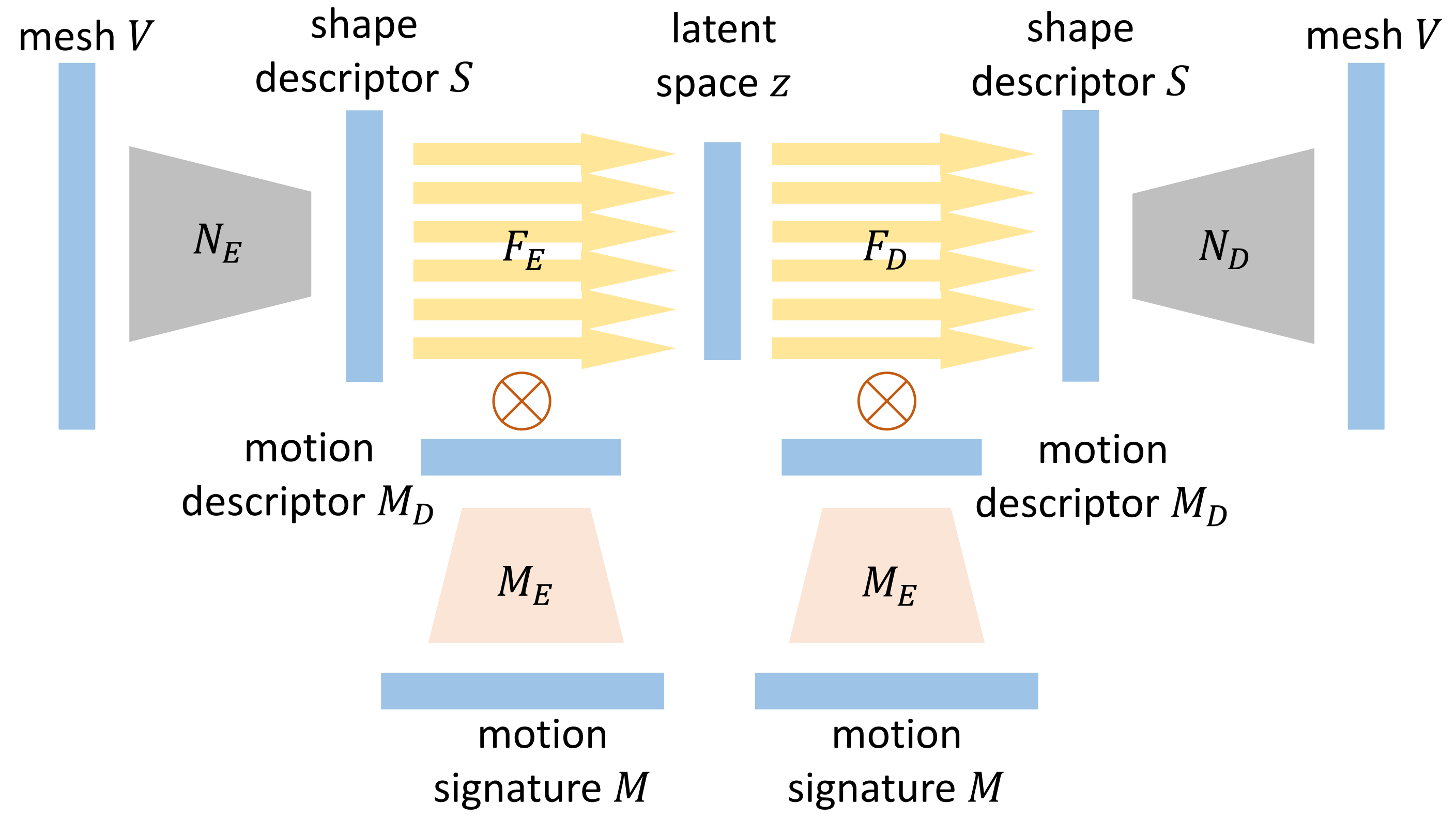
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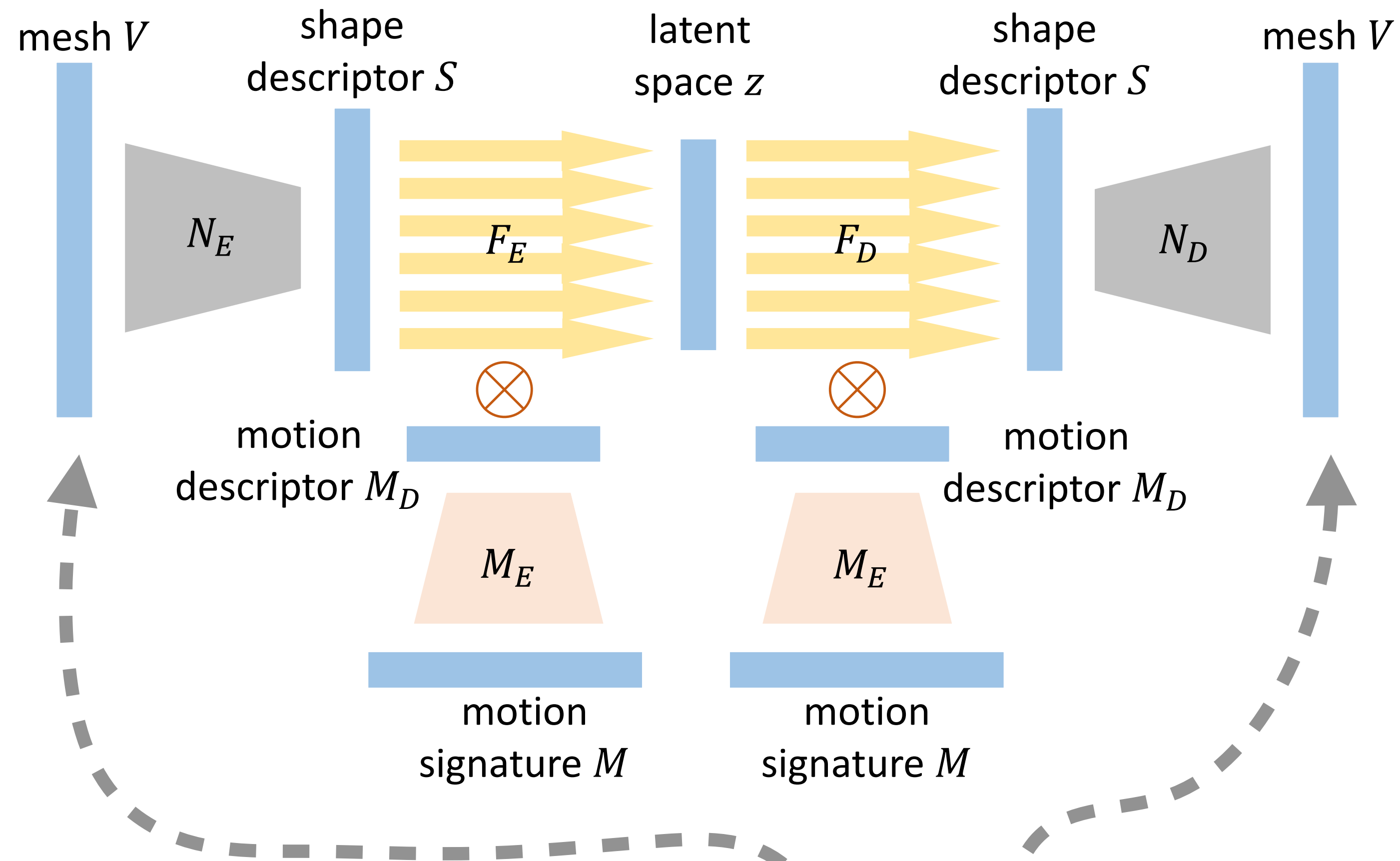
For a batch generated with the same parameters:

$$E = \mathbf{Var}(z) + \lambda \cdot \|S_i - S_i^*\|$$



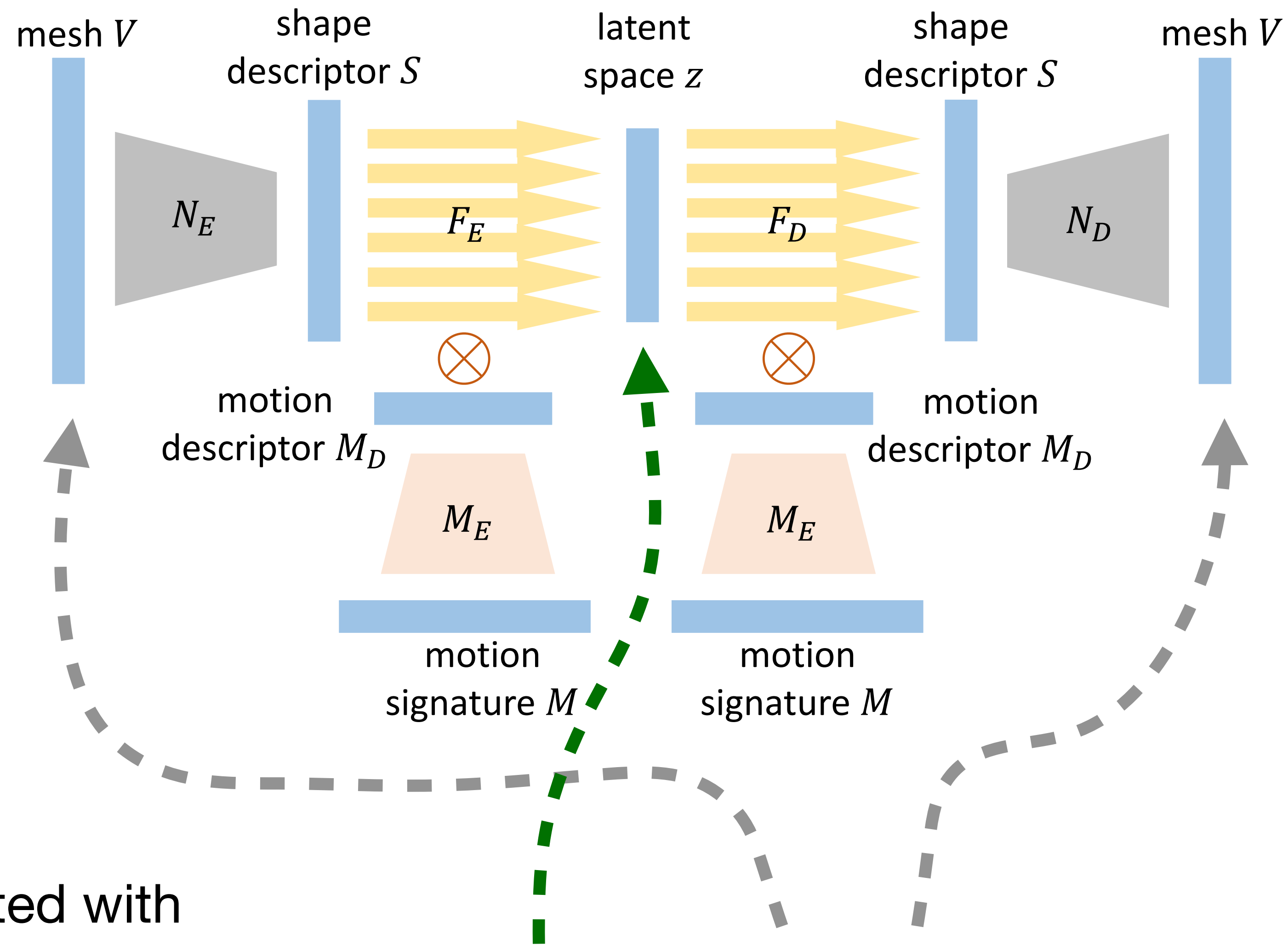
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For a batch generated with
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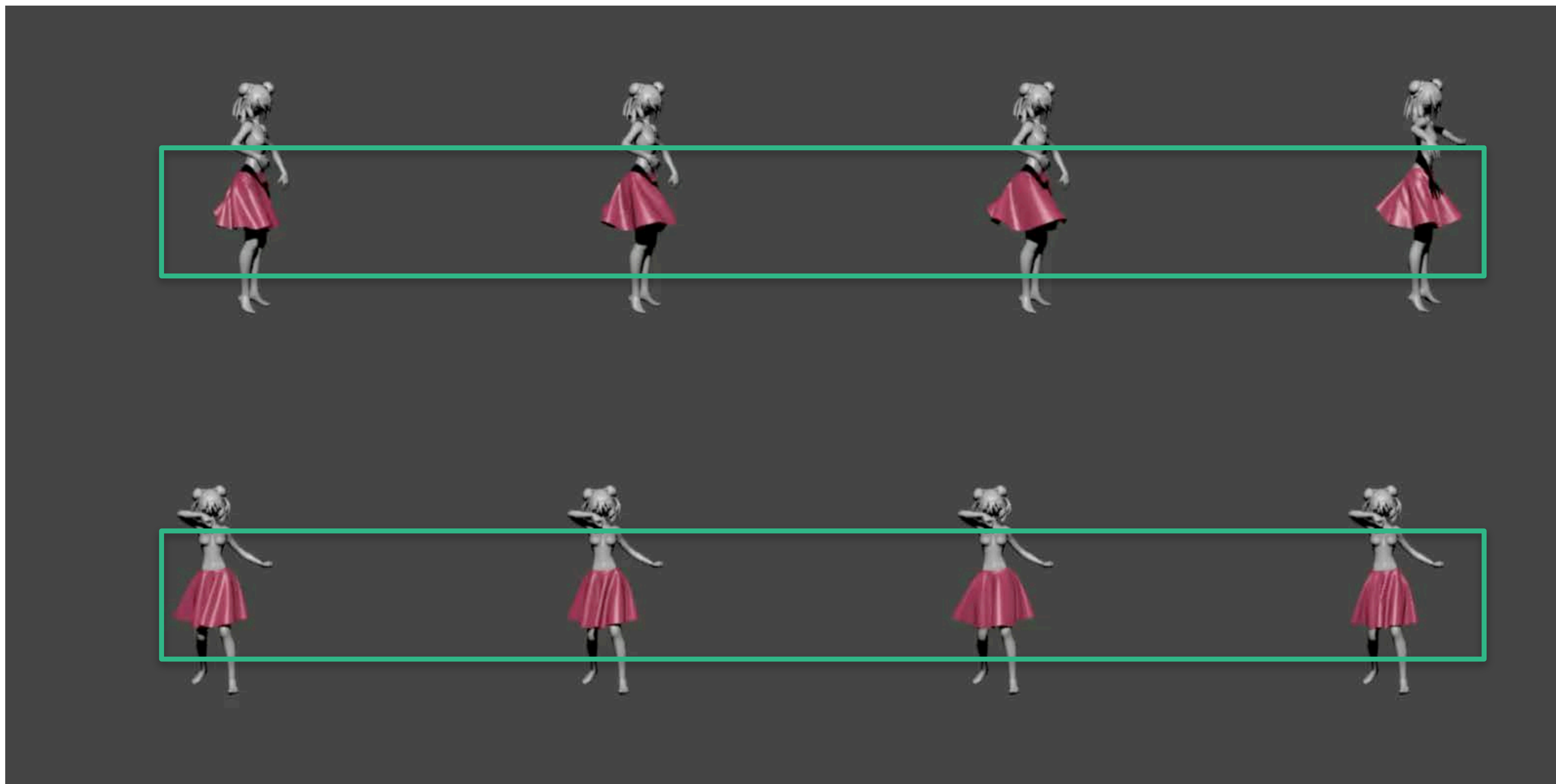
$$E = \mathbf{Var}(z) + \lambda \cdot \|S_i - S_i^*\|$$



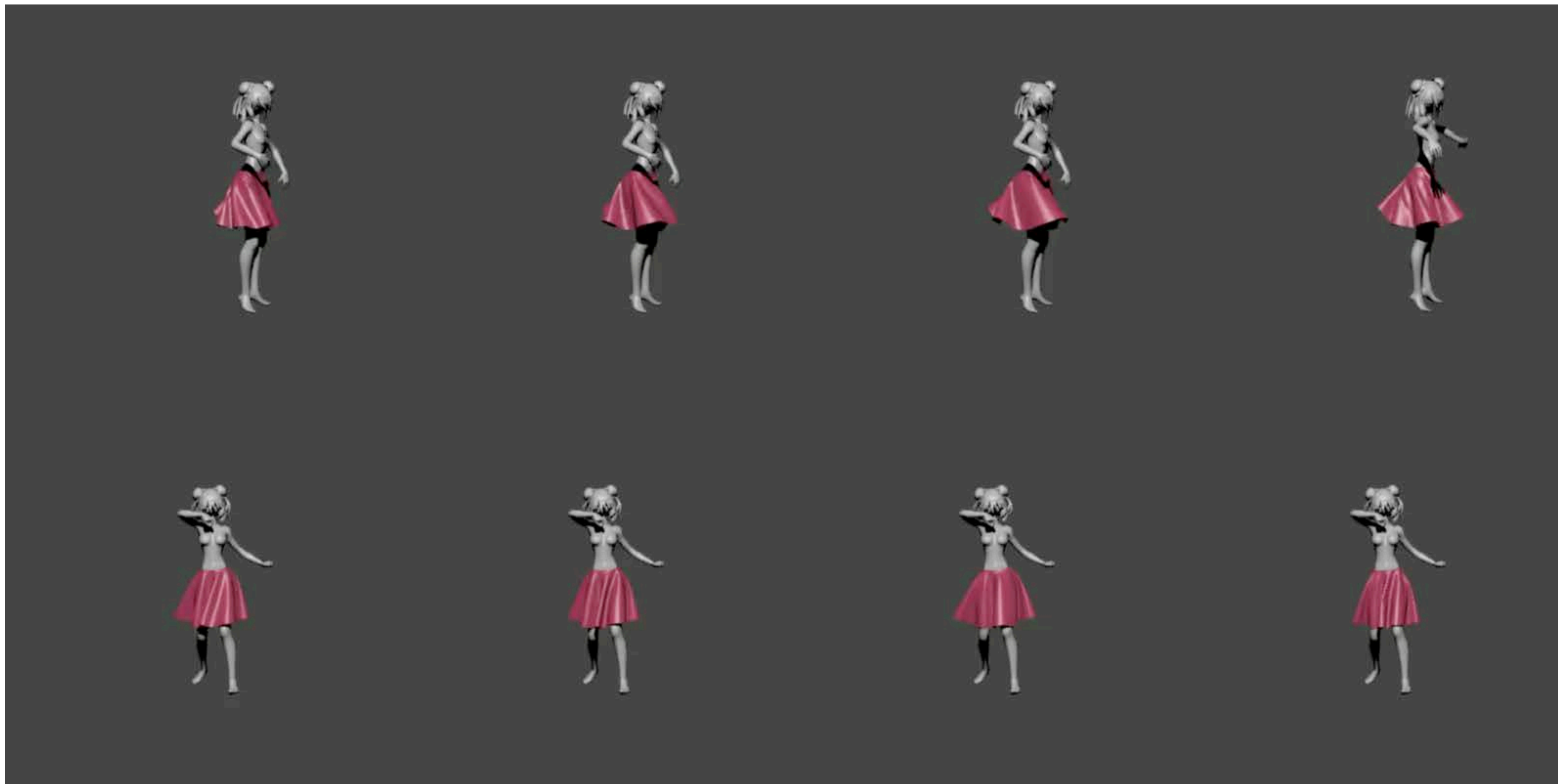
For a batch generated with
the same parameters:

$$E = \mathbf{Var}(z) + \lambda \cdot \|S_i - S_i^*\|$$

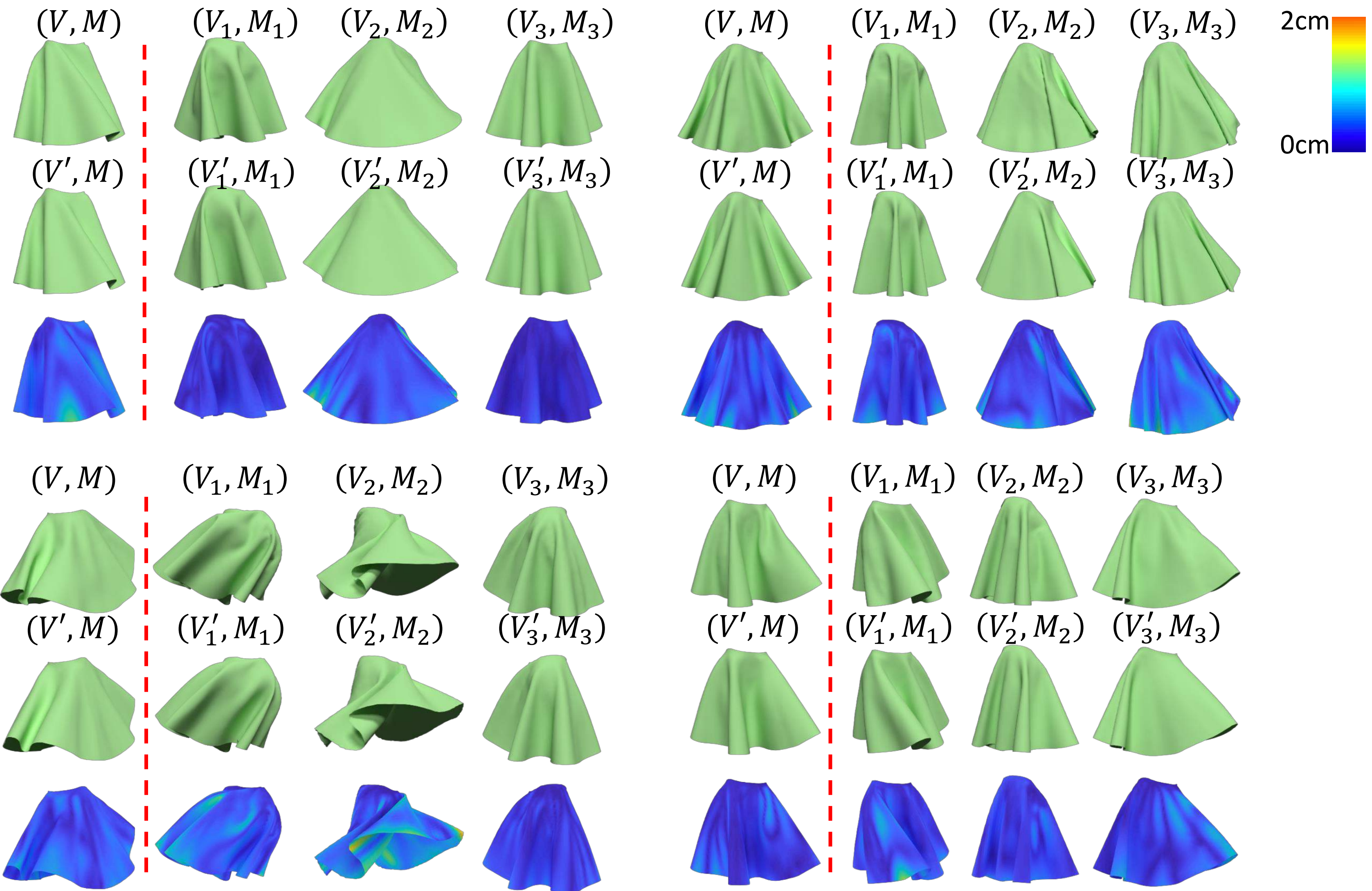
Data generation



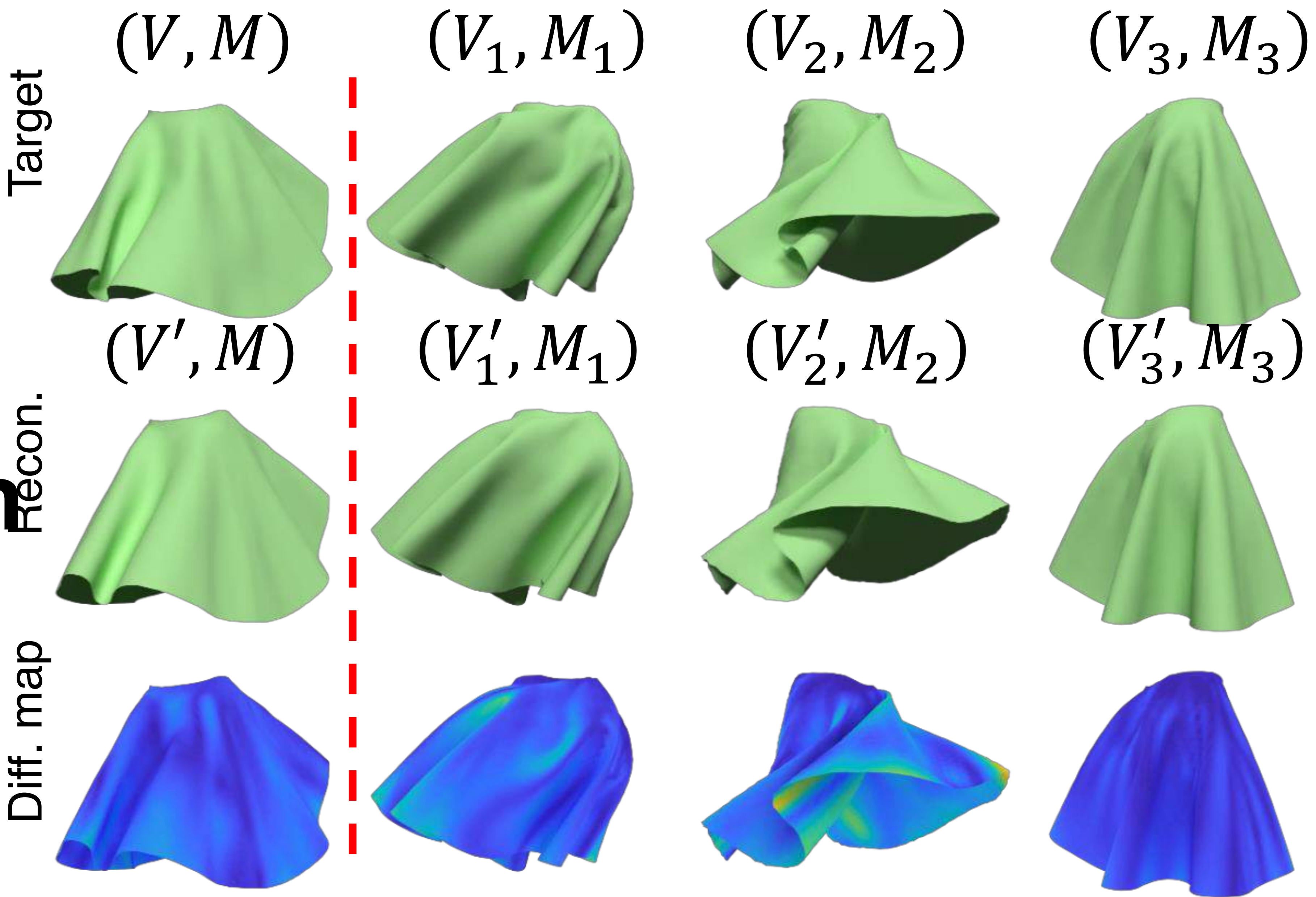
Data generation



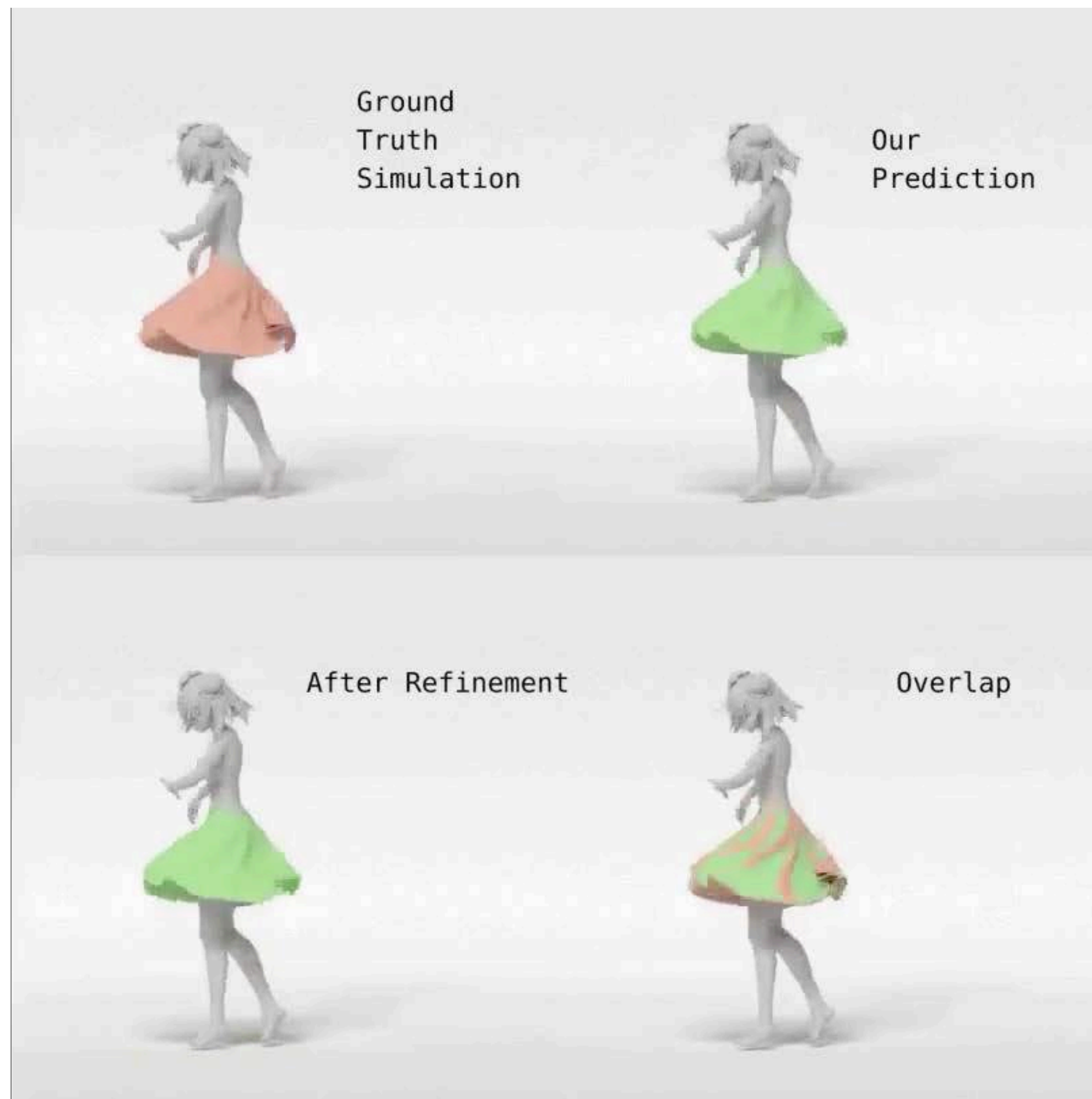
Evaluation



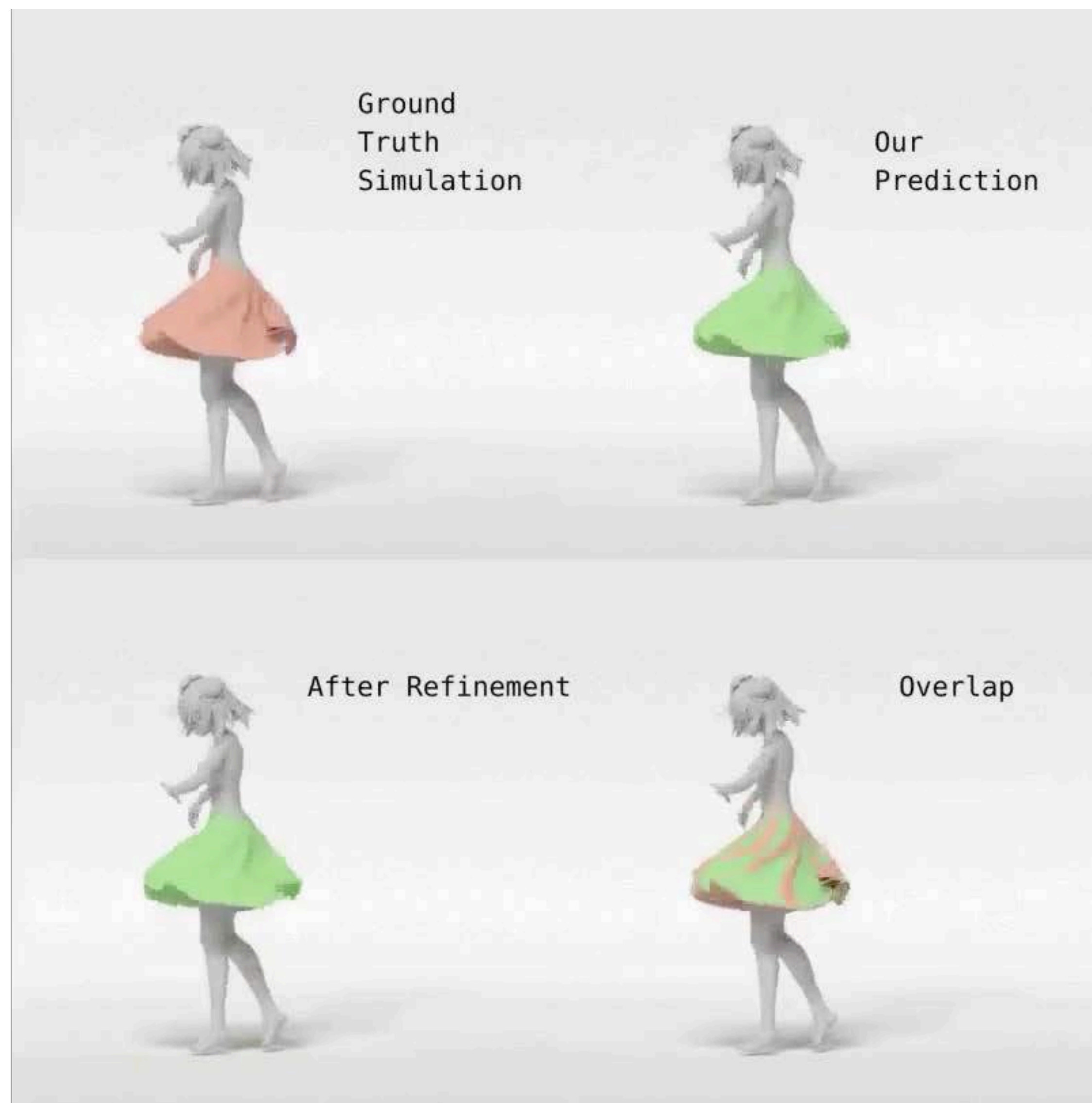
Evaluation



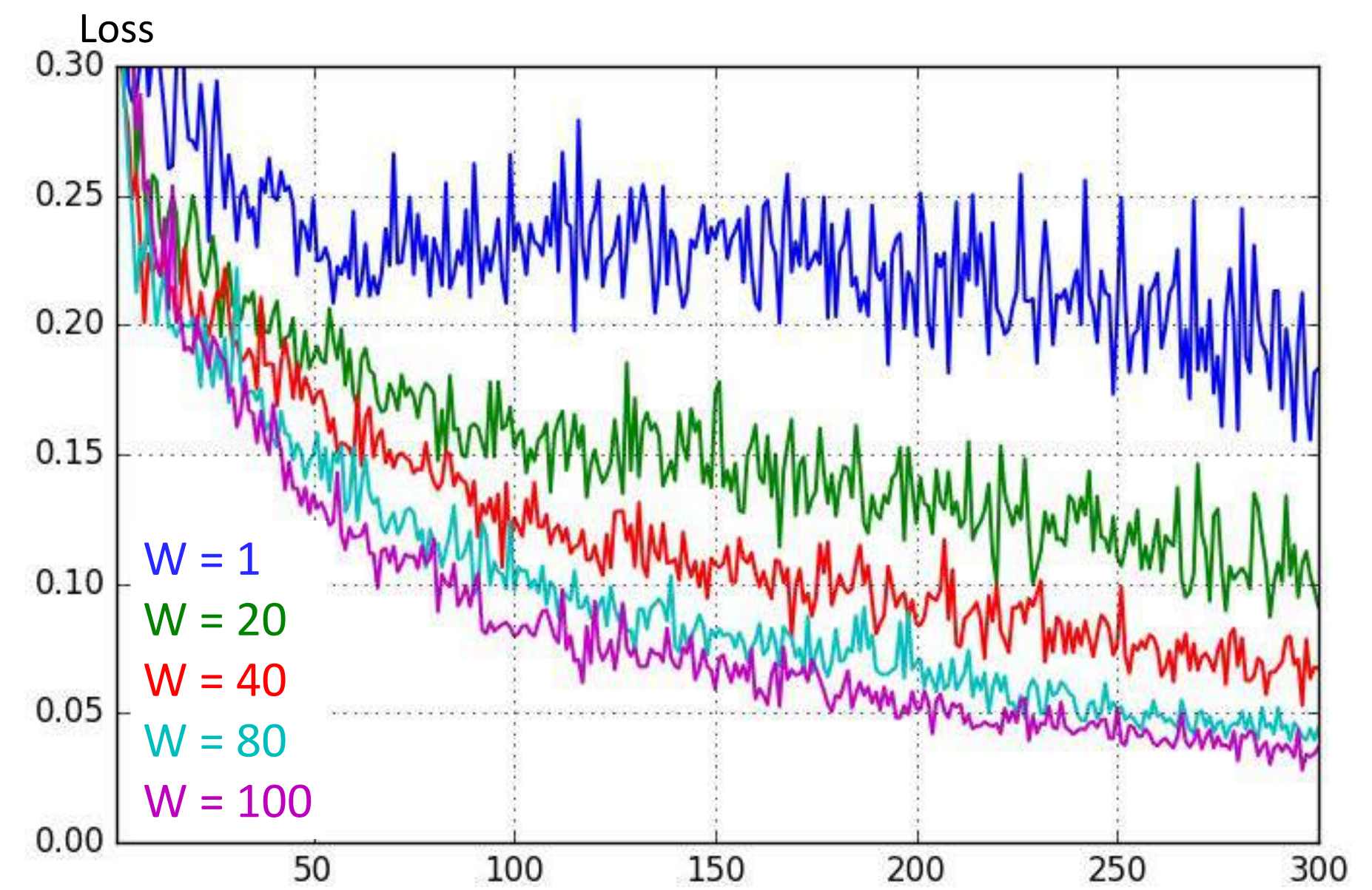
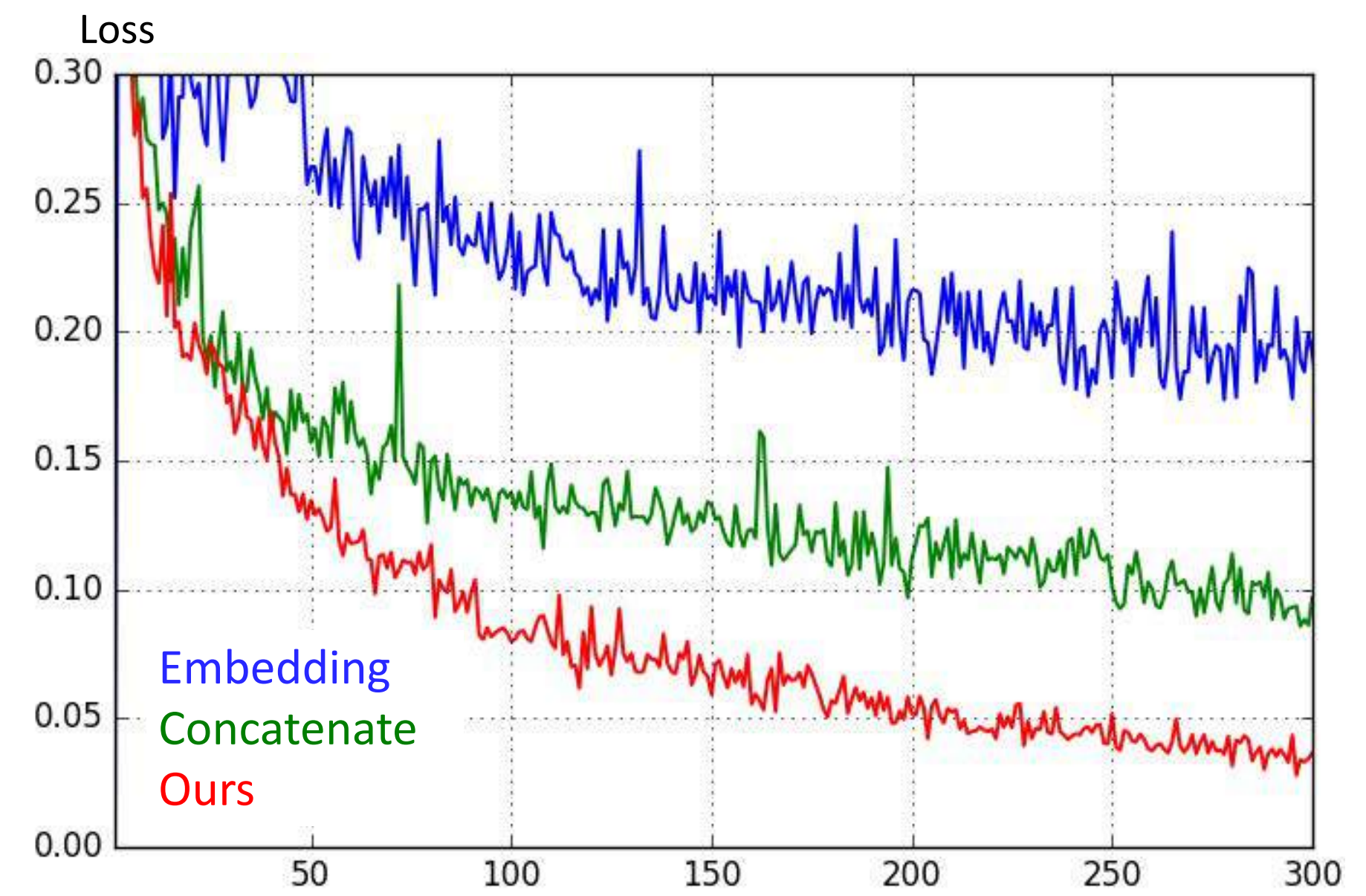
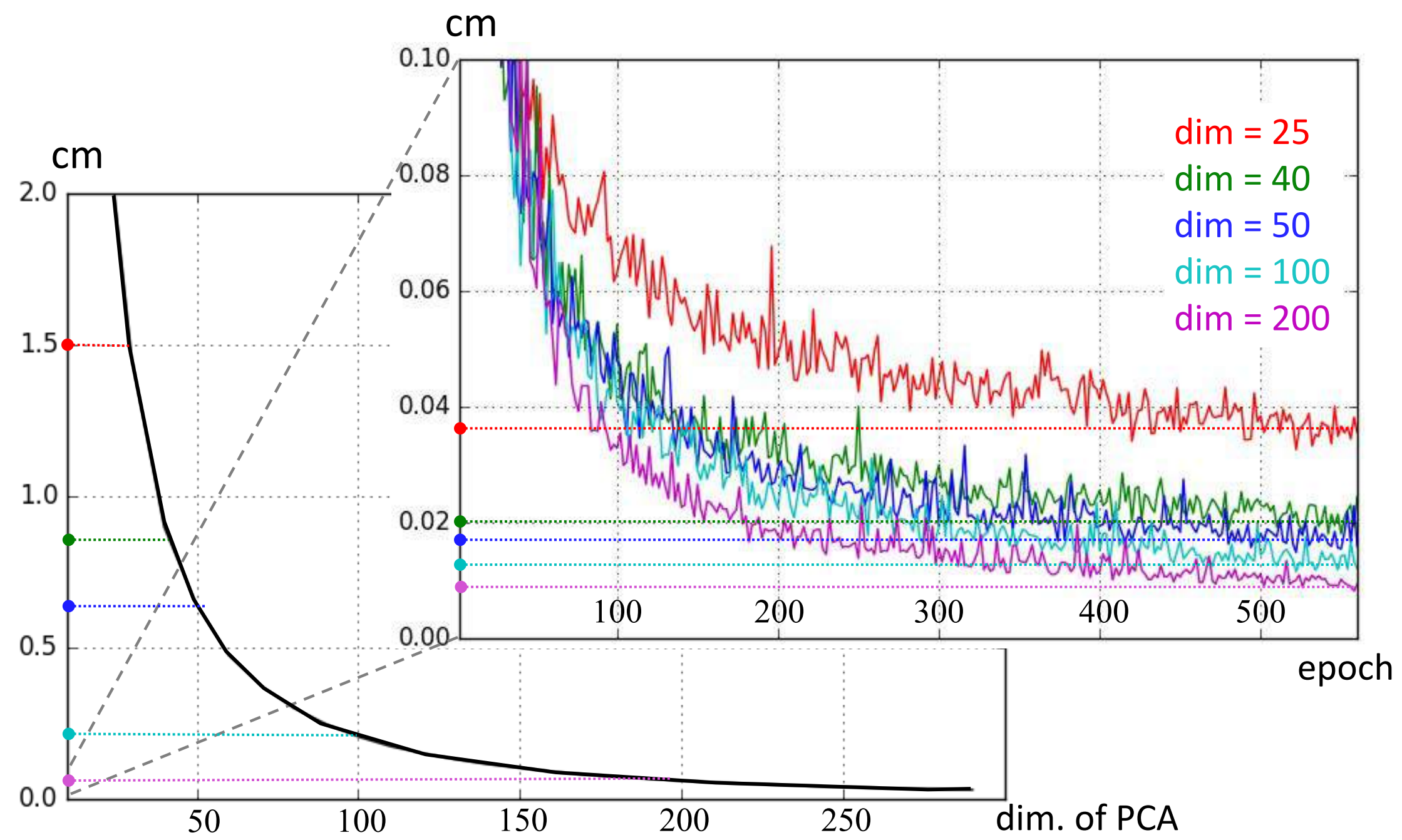
Evaluation



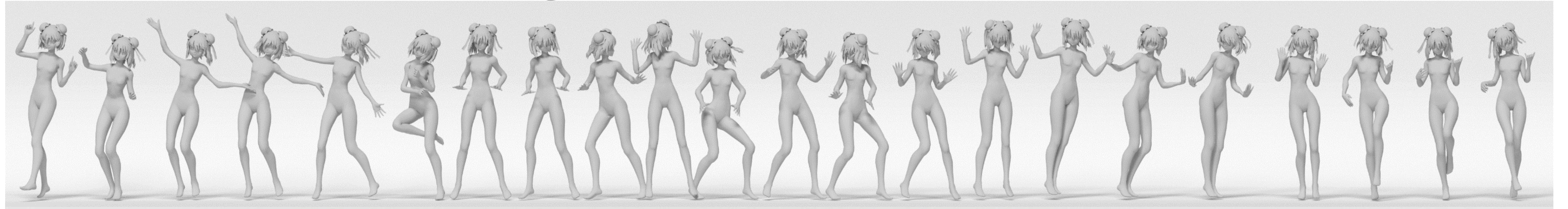
Evaluation



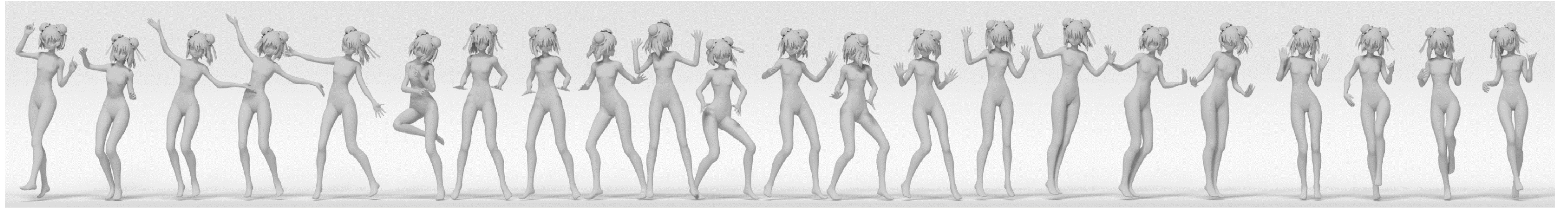
Evaluation



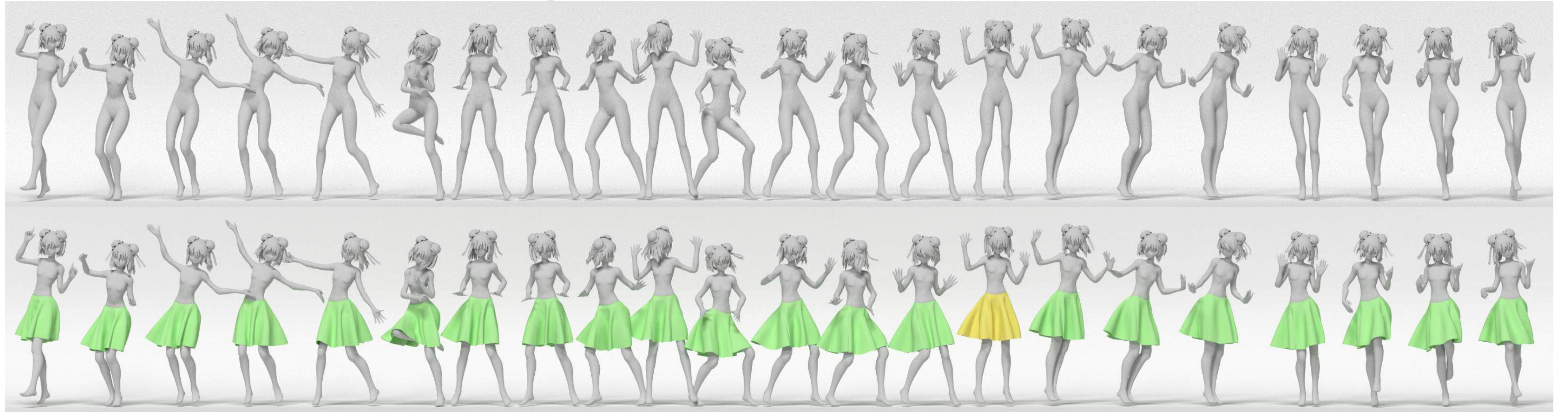
Interactive design pipeline



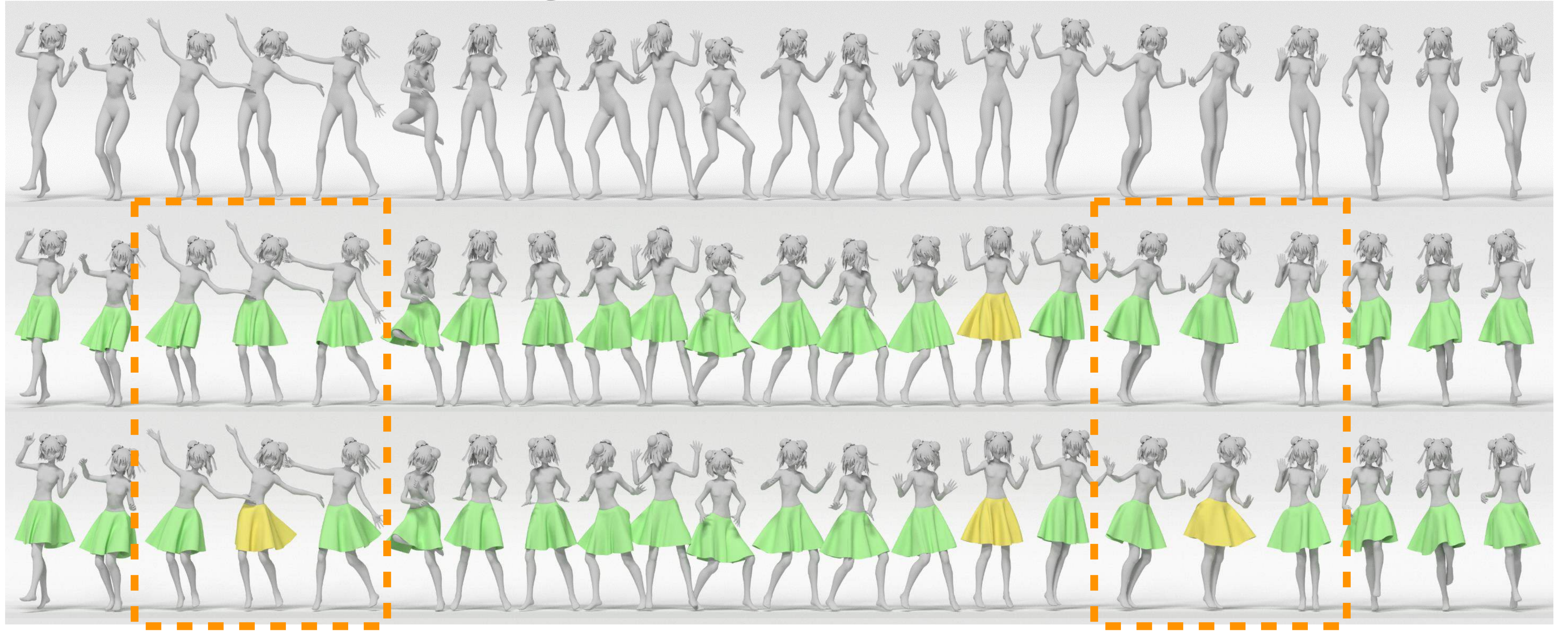
Interactive design pipeline



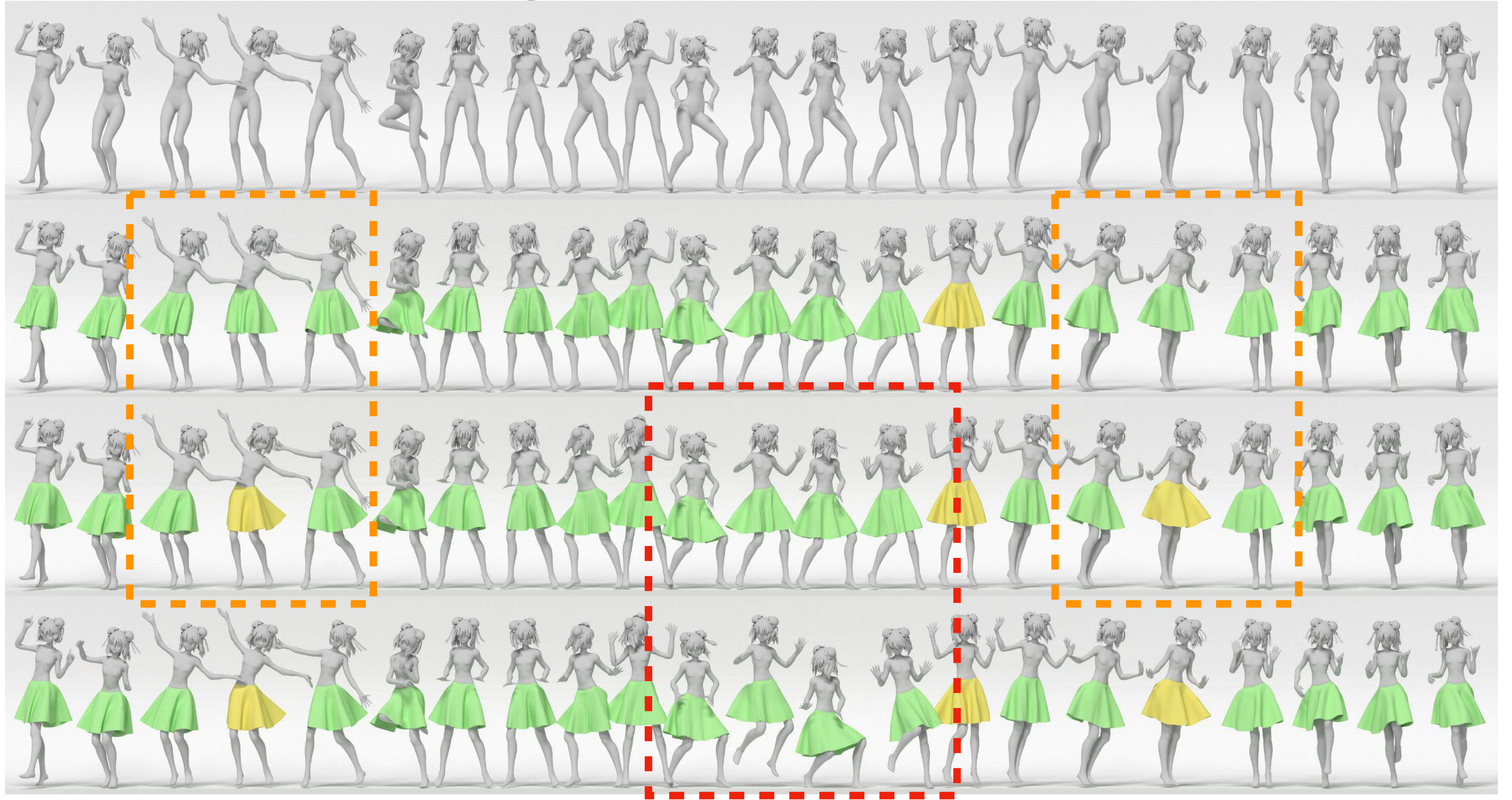
Interactive design pipeline

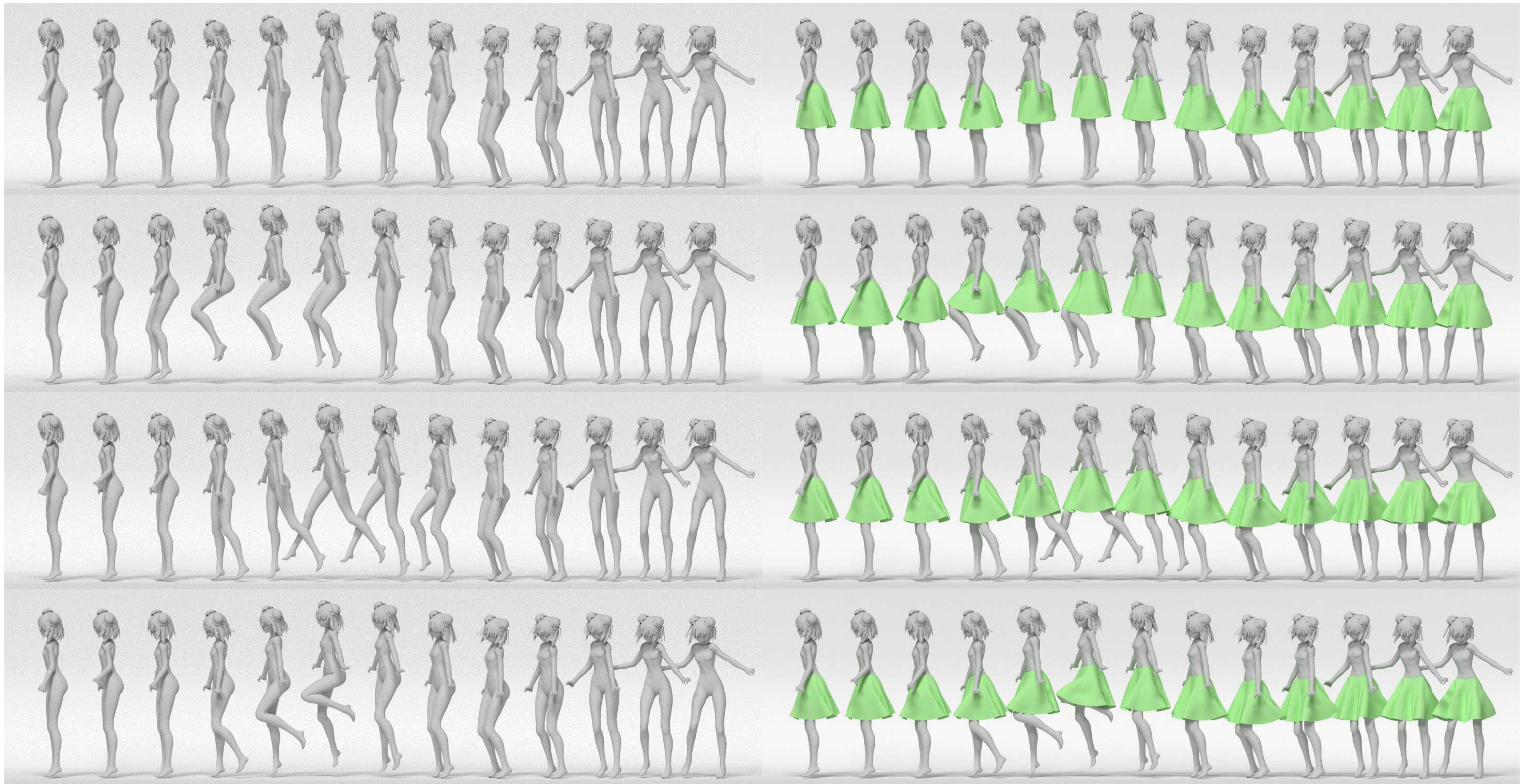


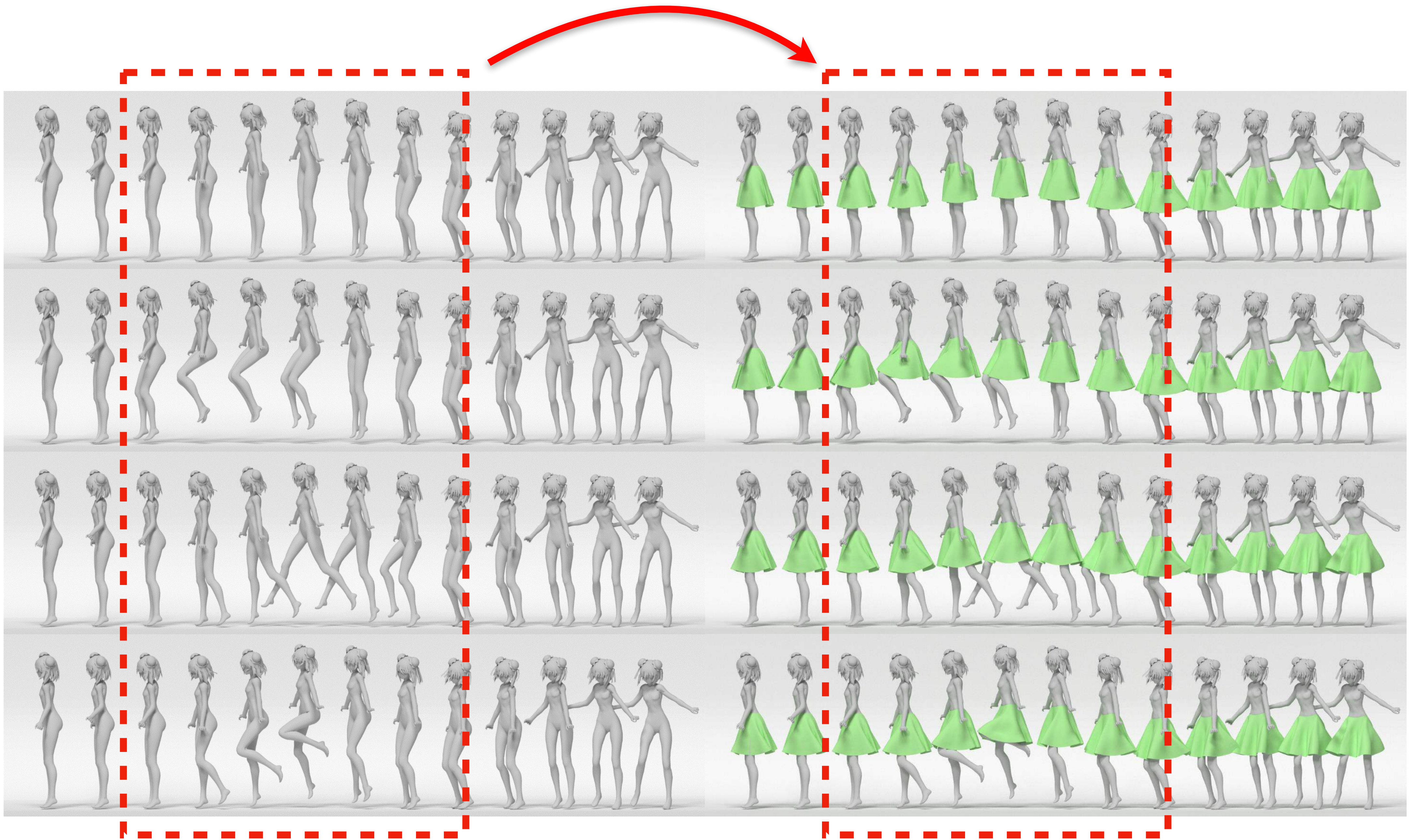
Interactive design pipeline



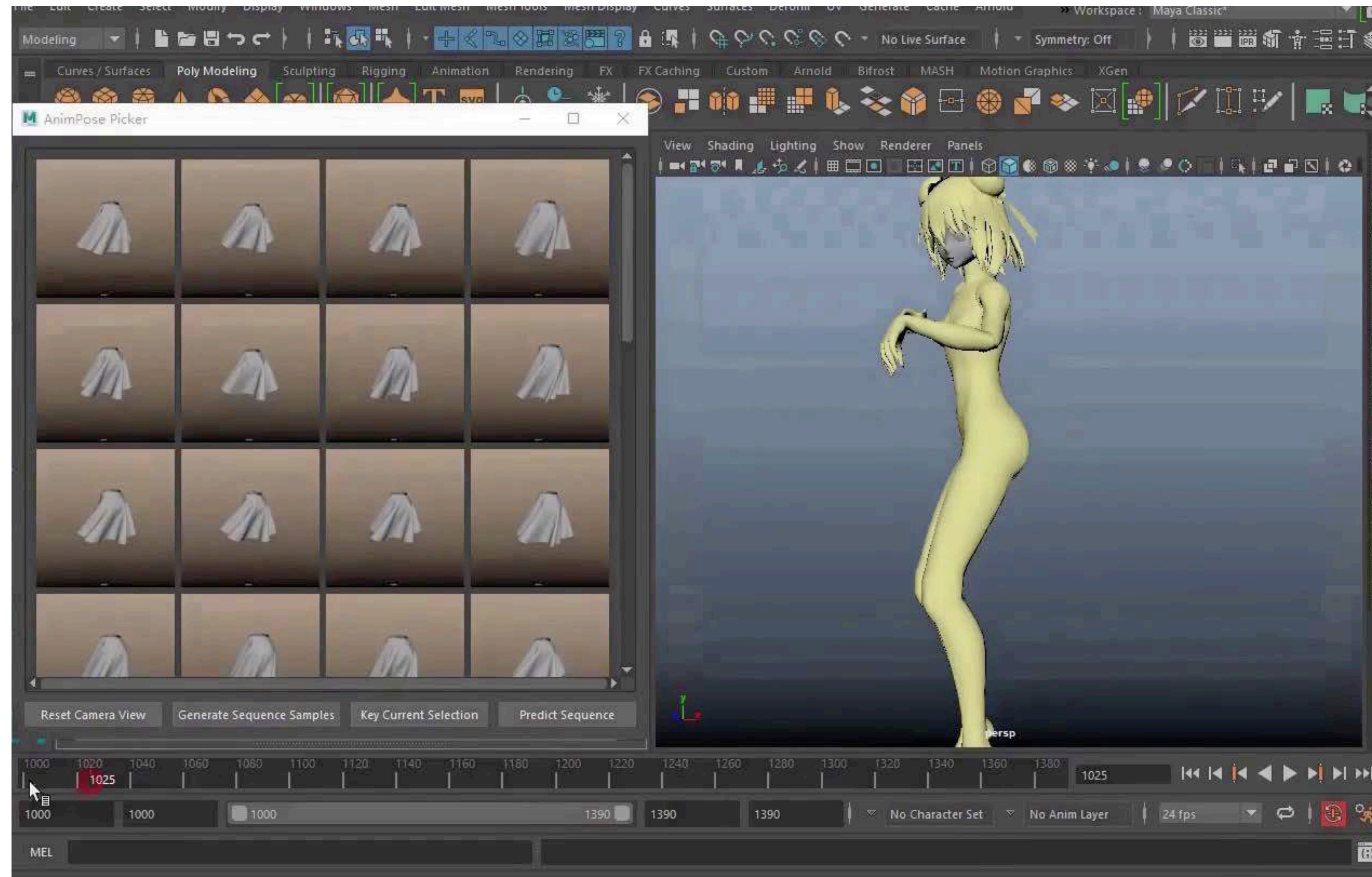
Interactive design pipeline



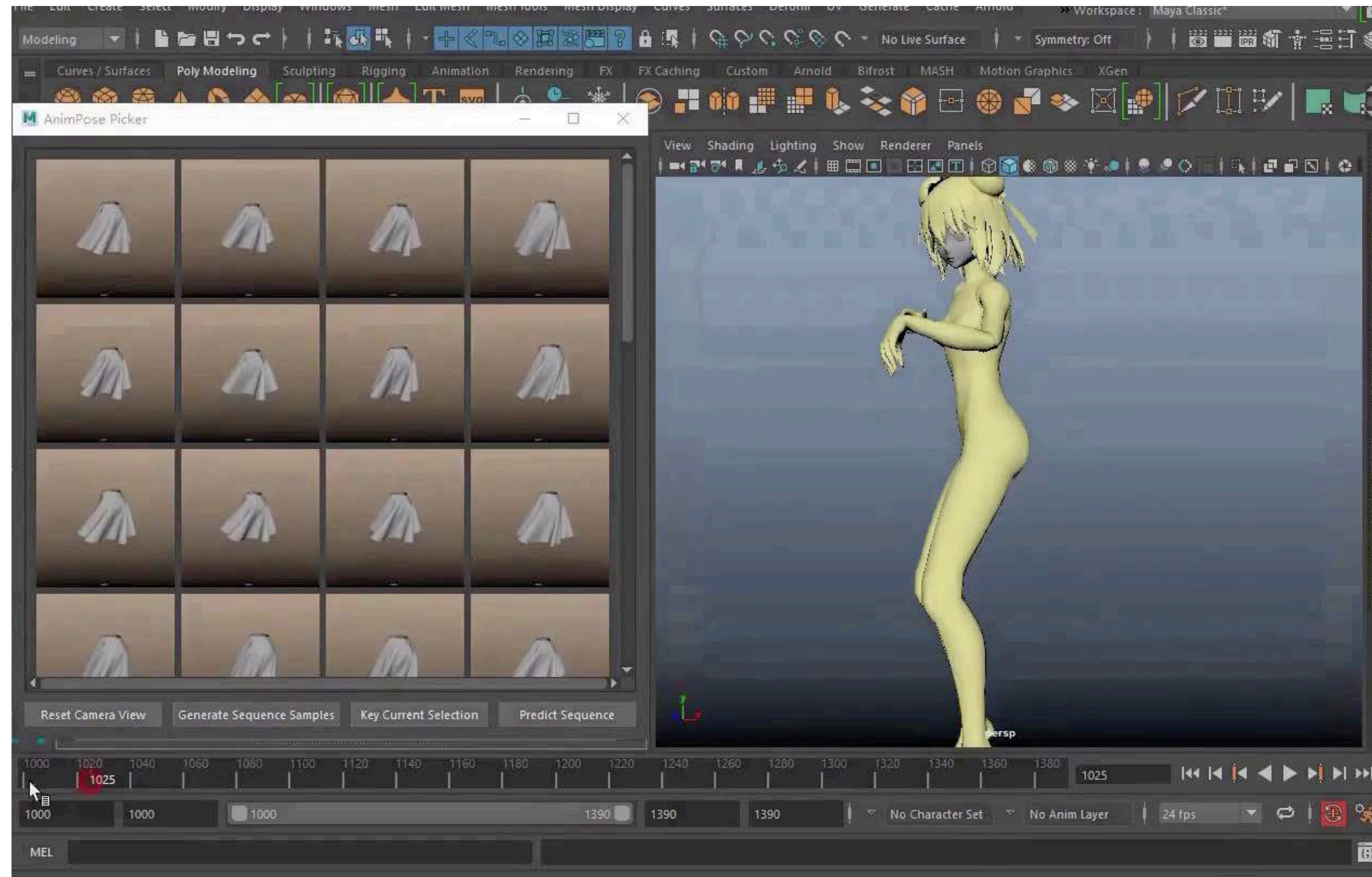




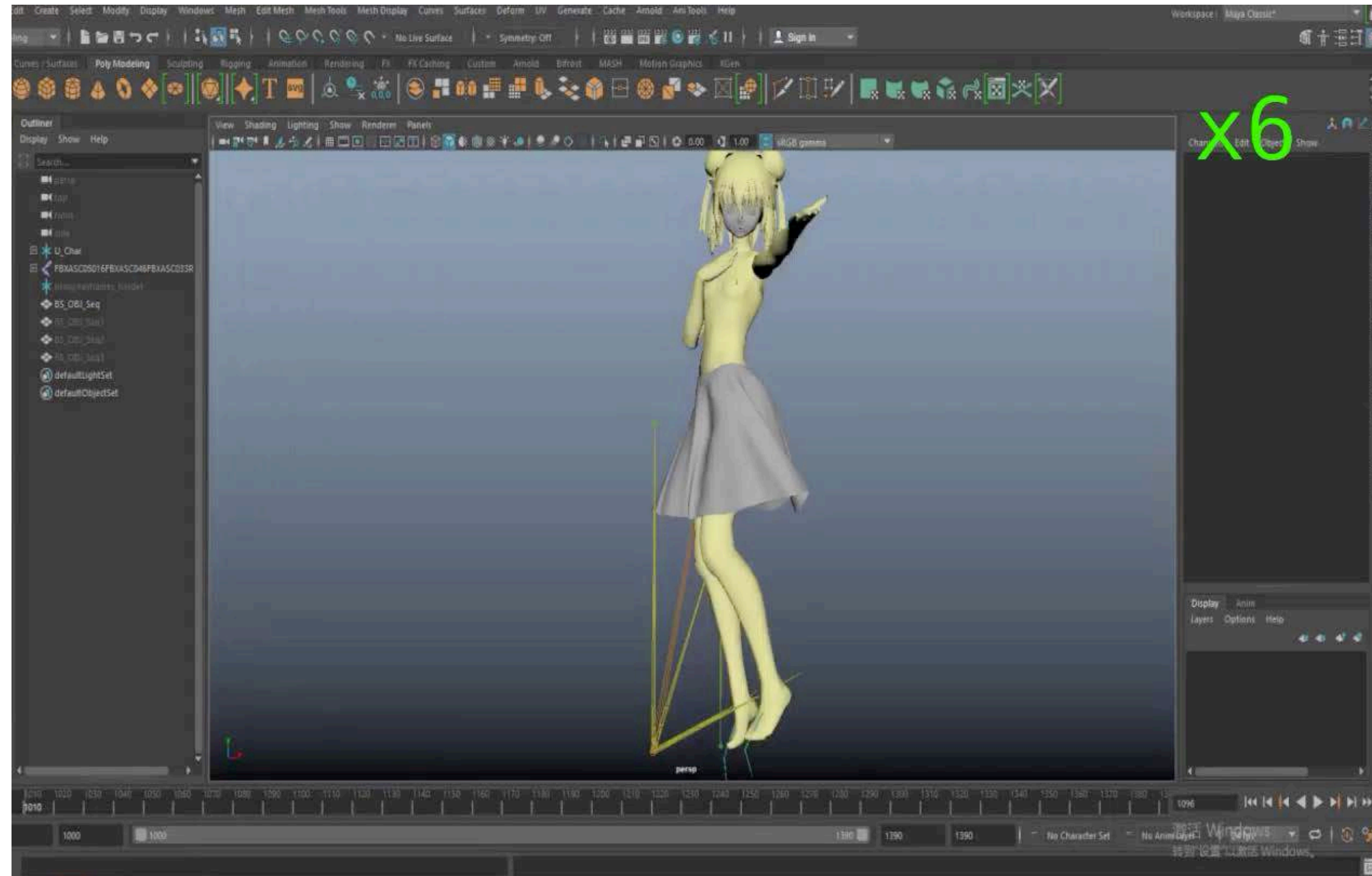
User interface



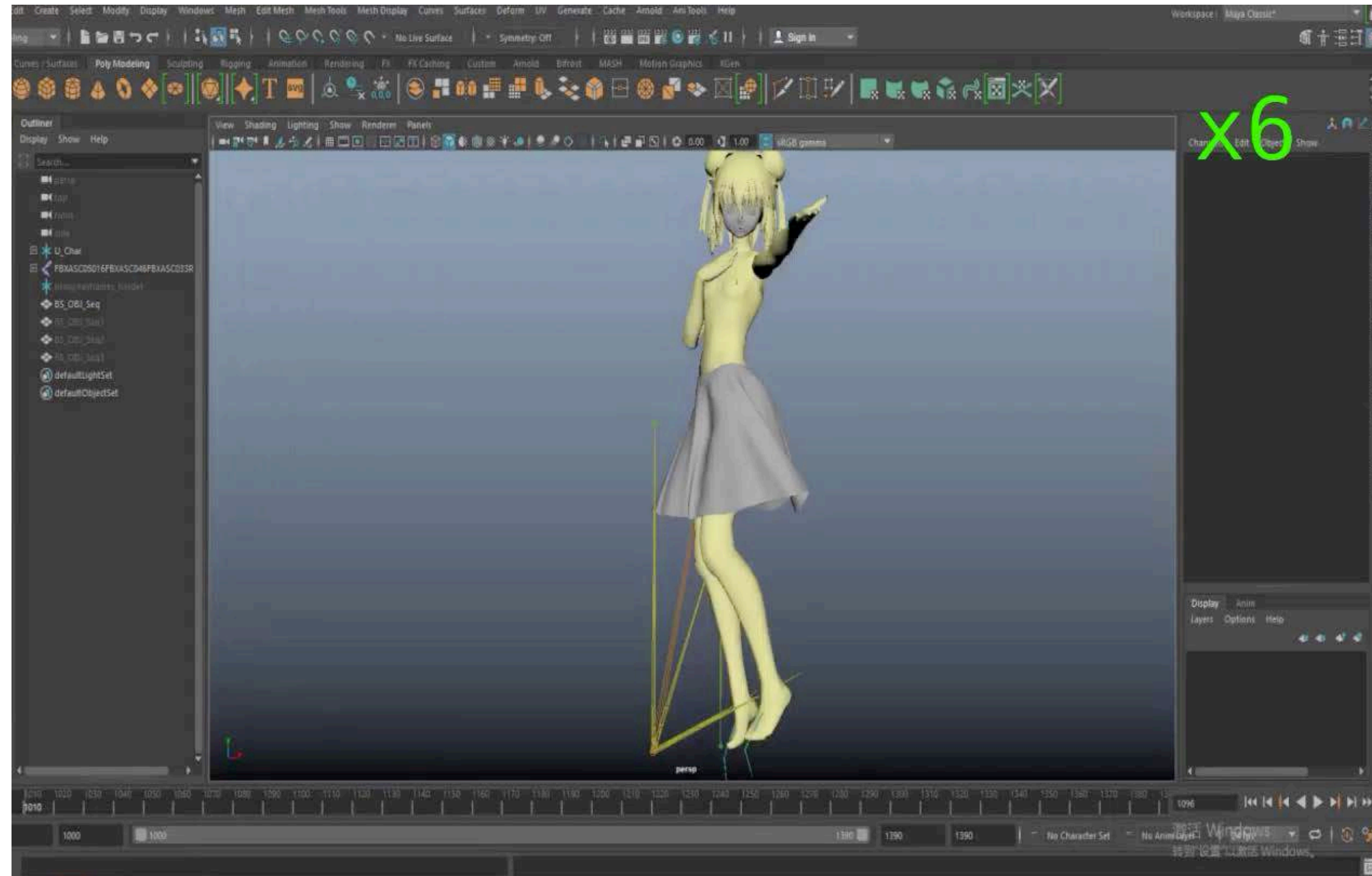
User interface



User interface



User interface



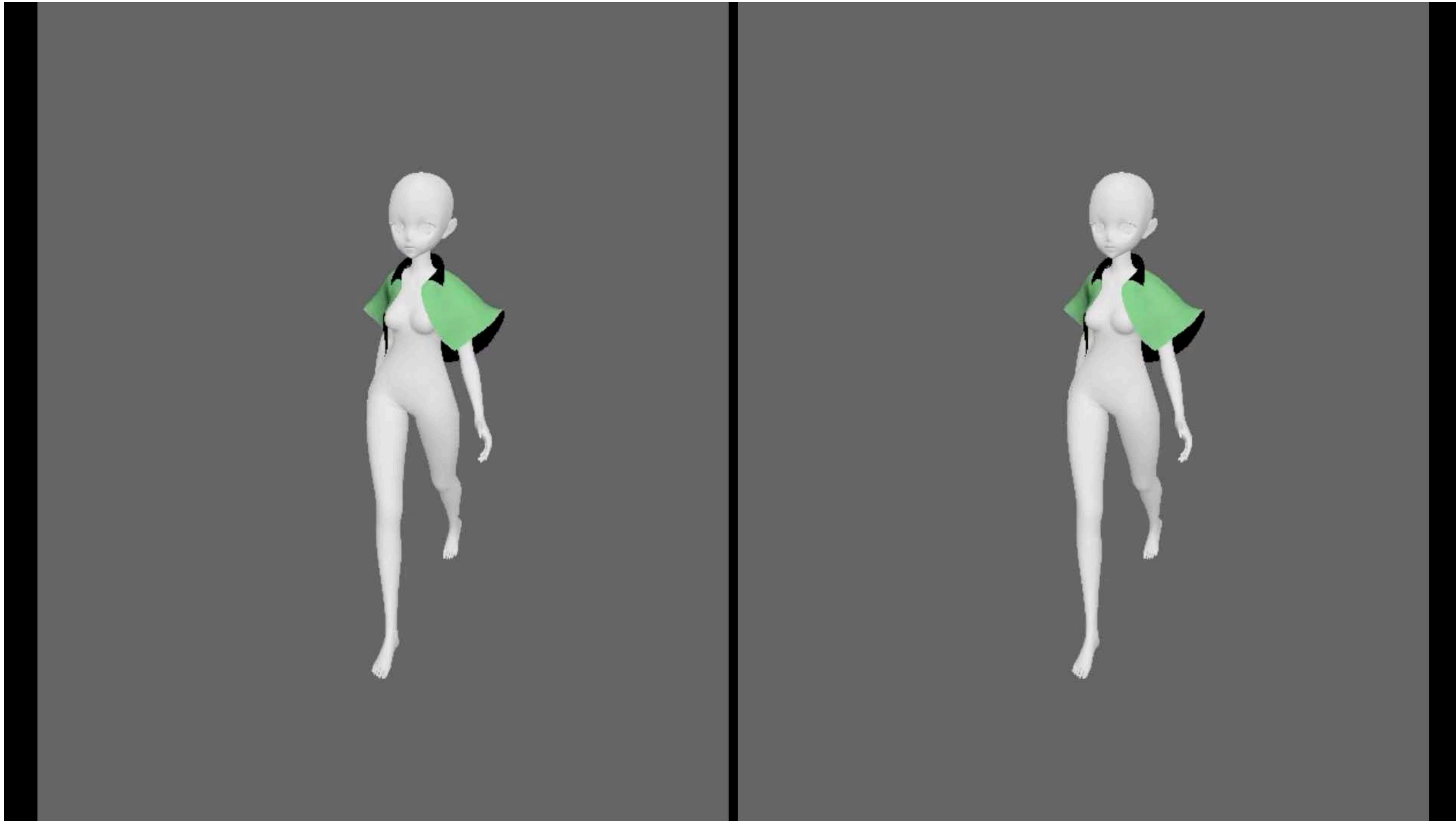
More results



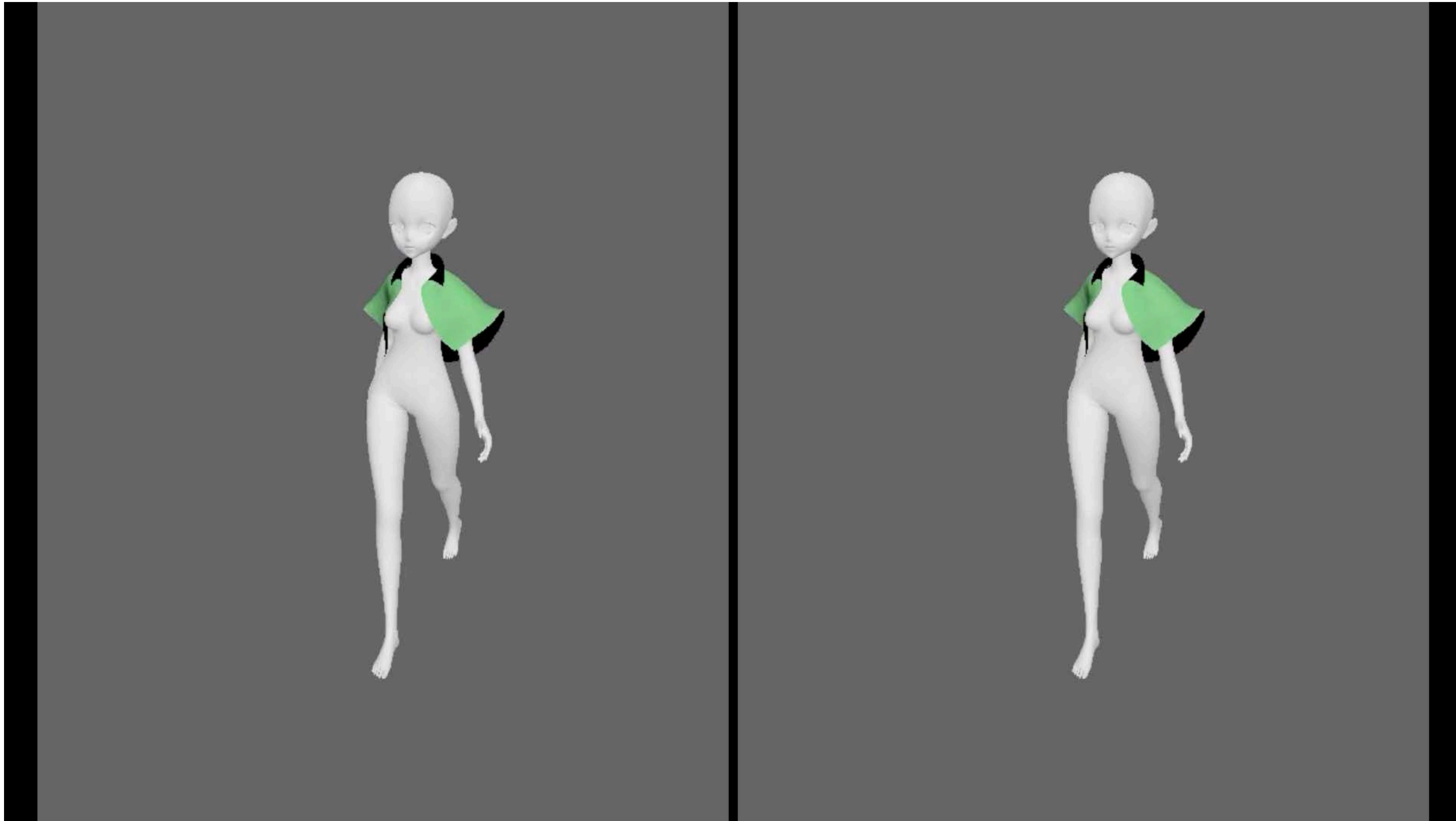
More results



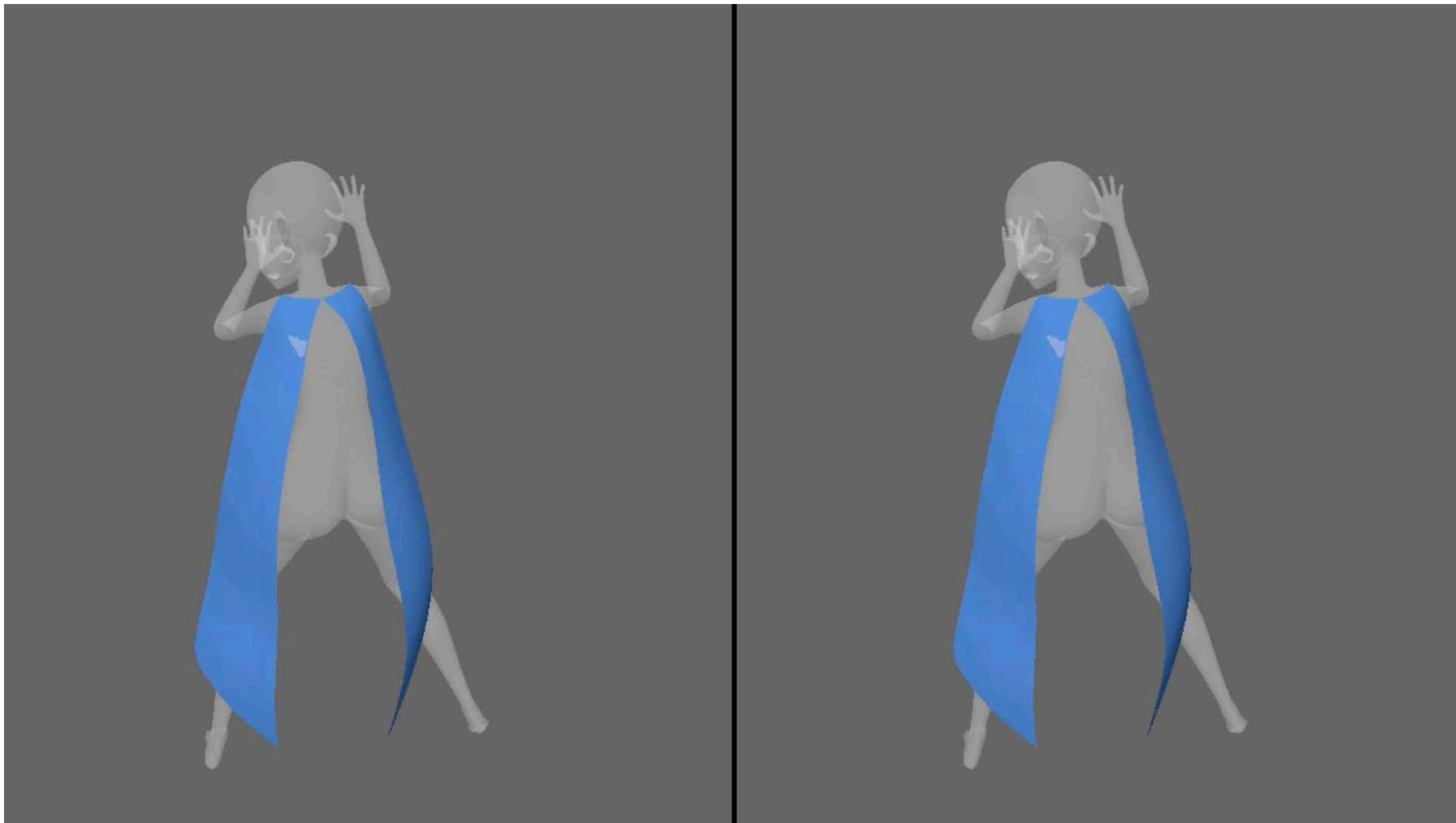
More results



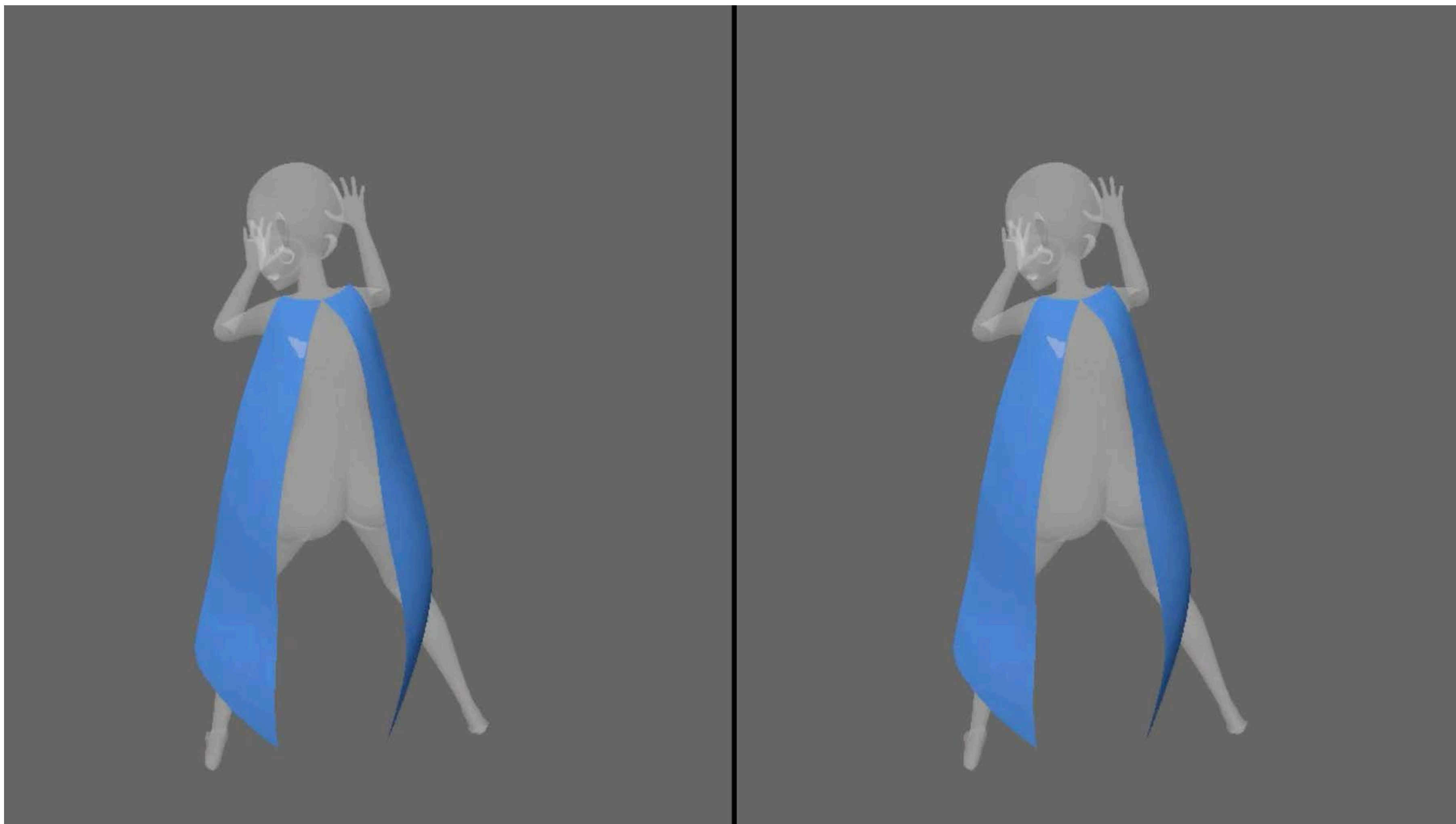
More results



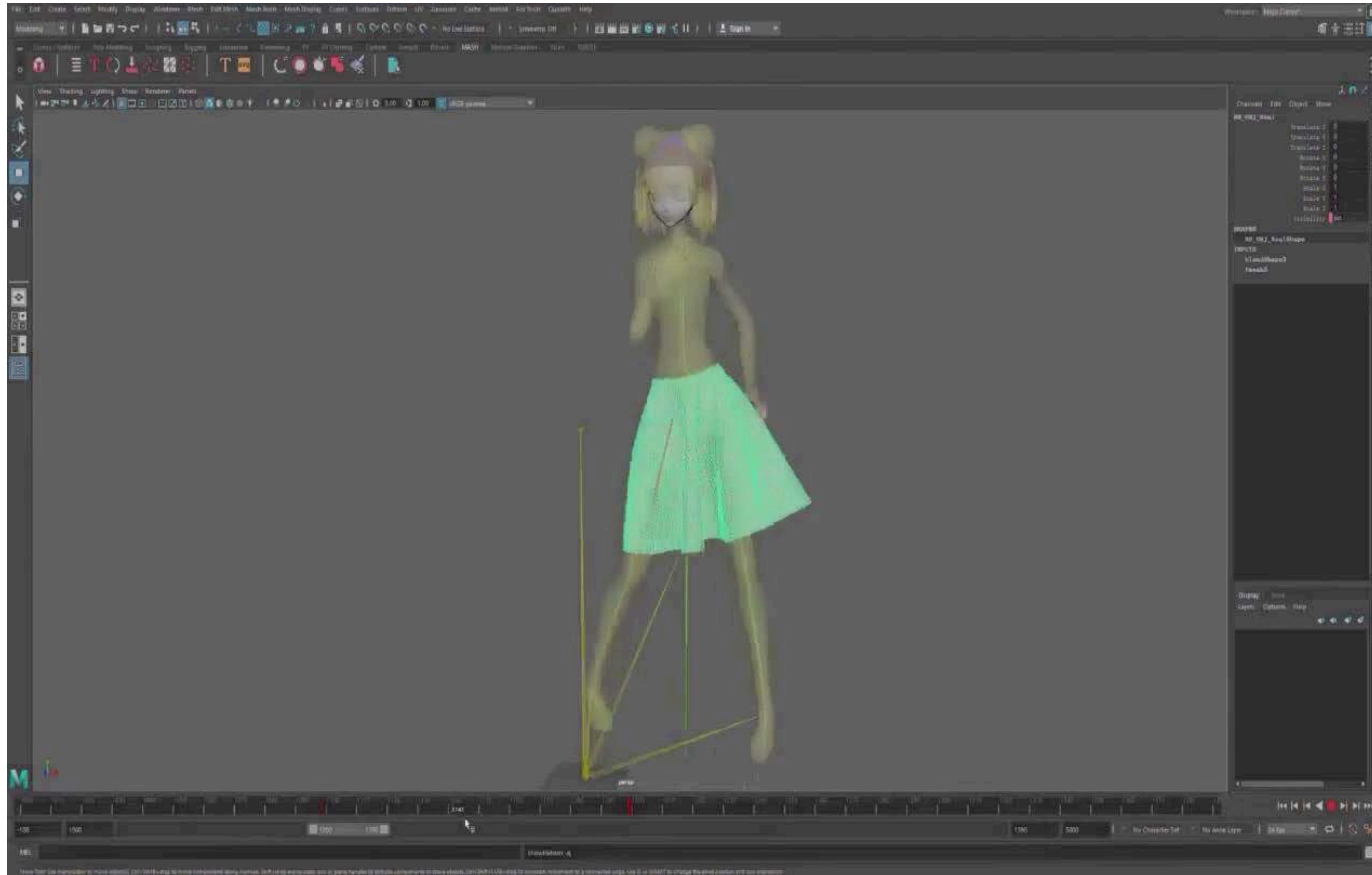
More results



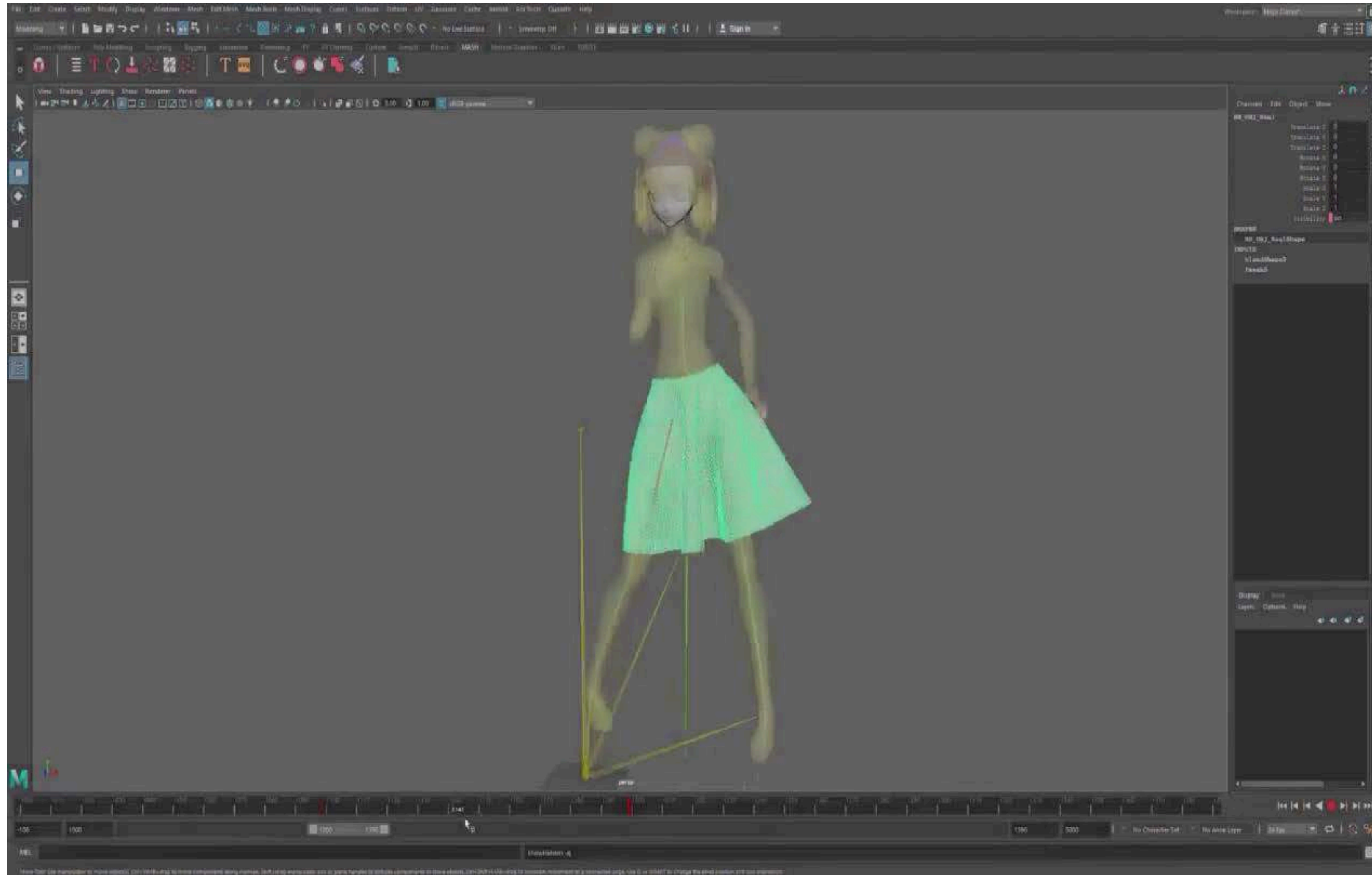
More results



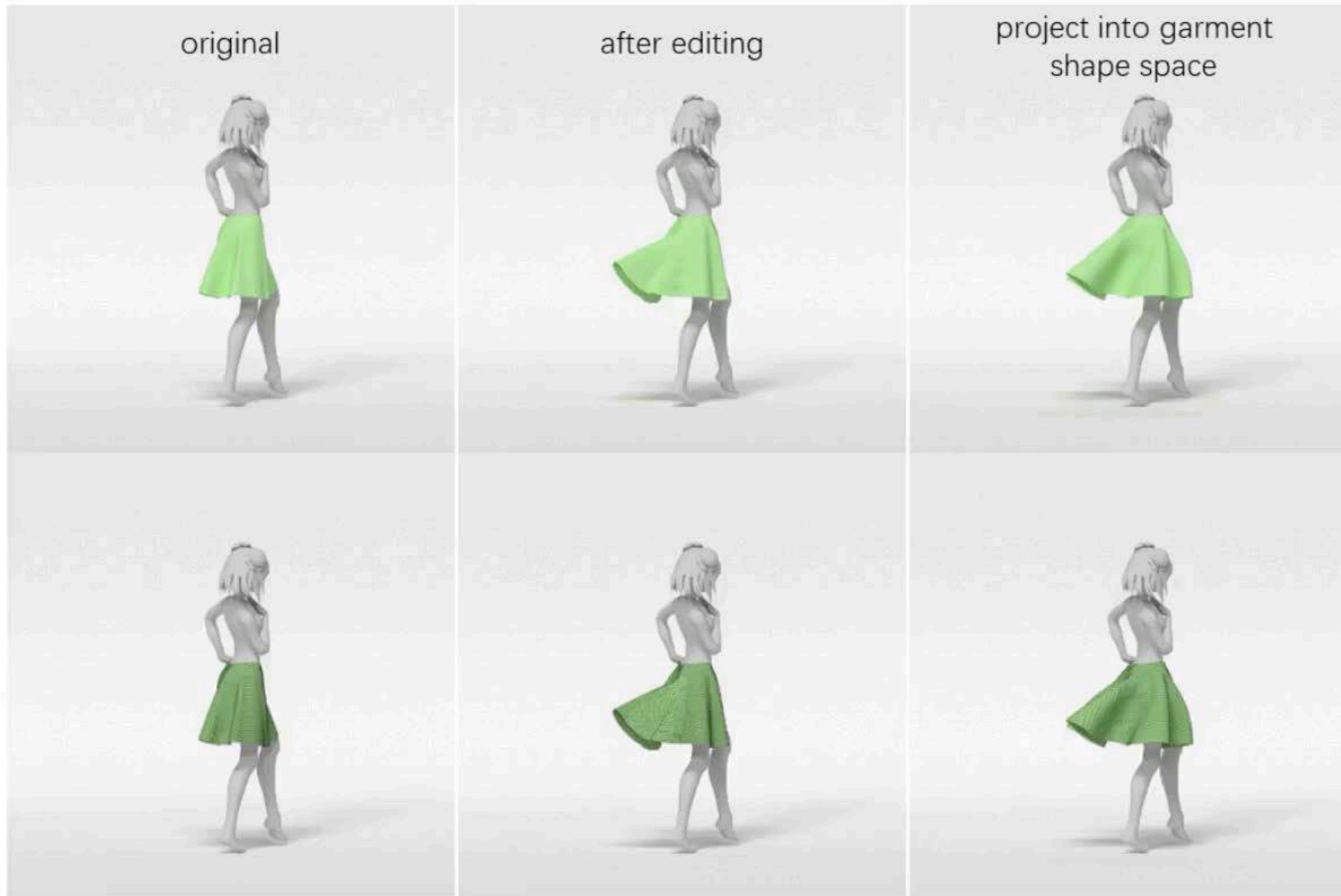
Free editing



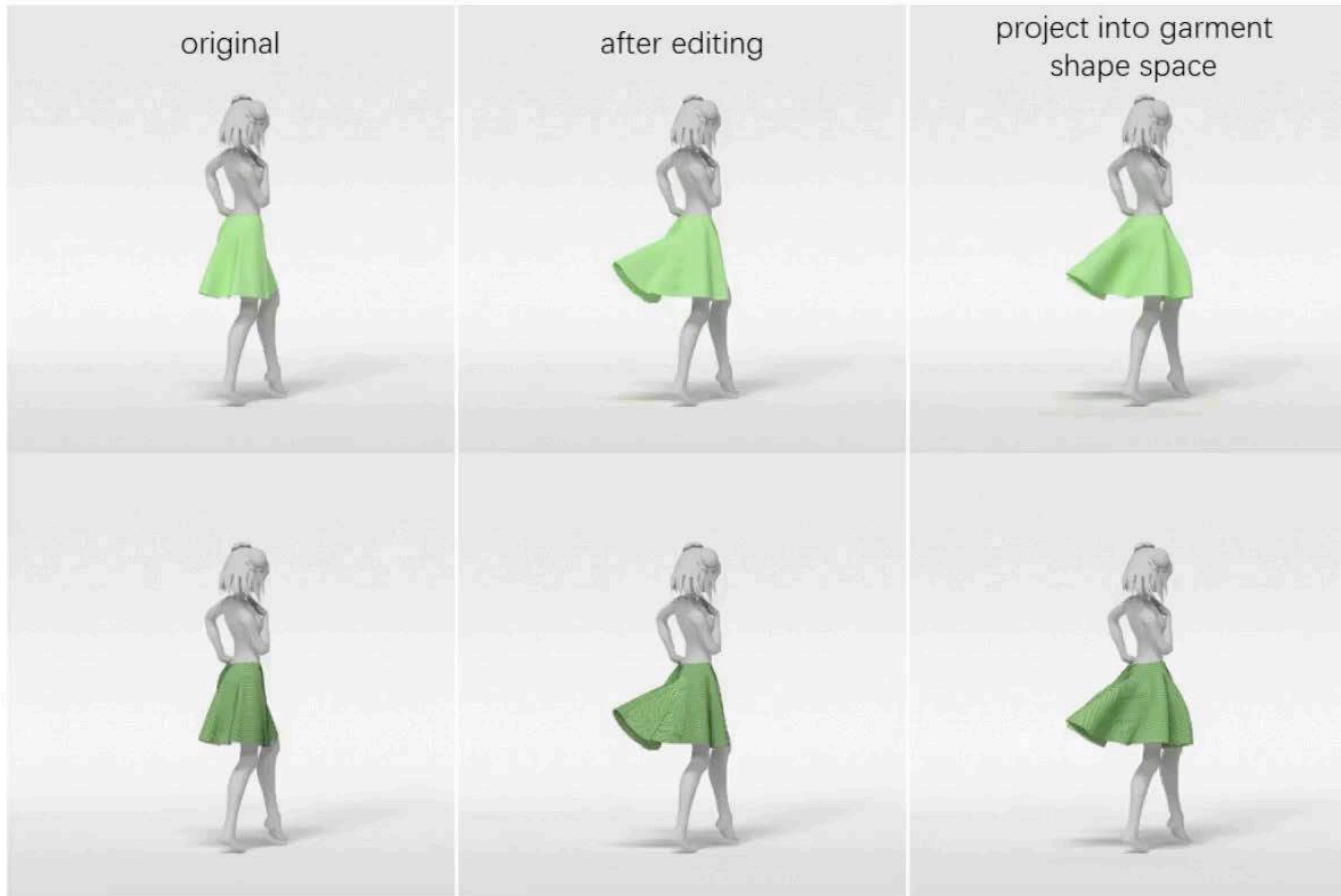
Free editing



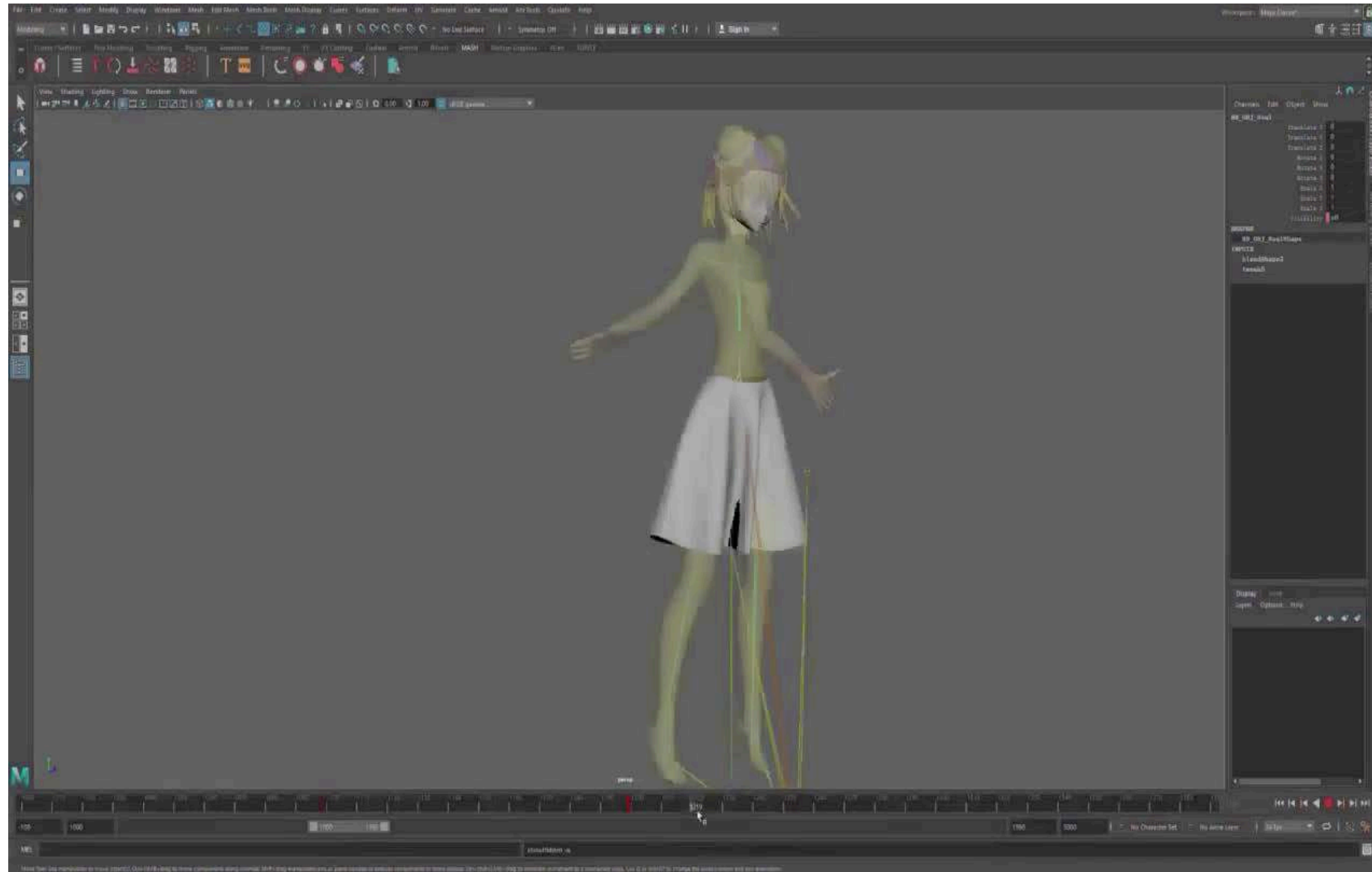
Free editing



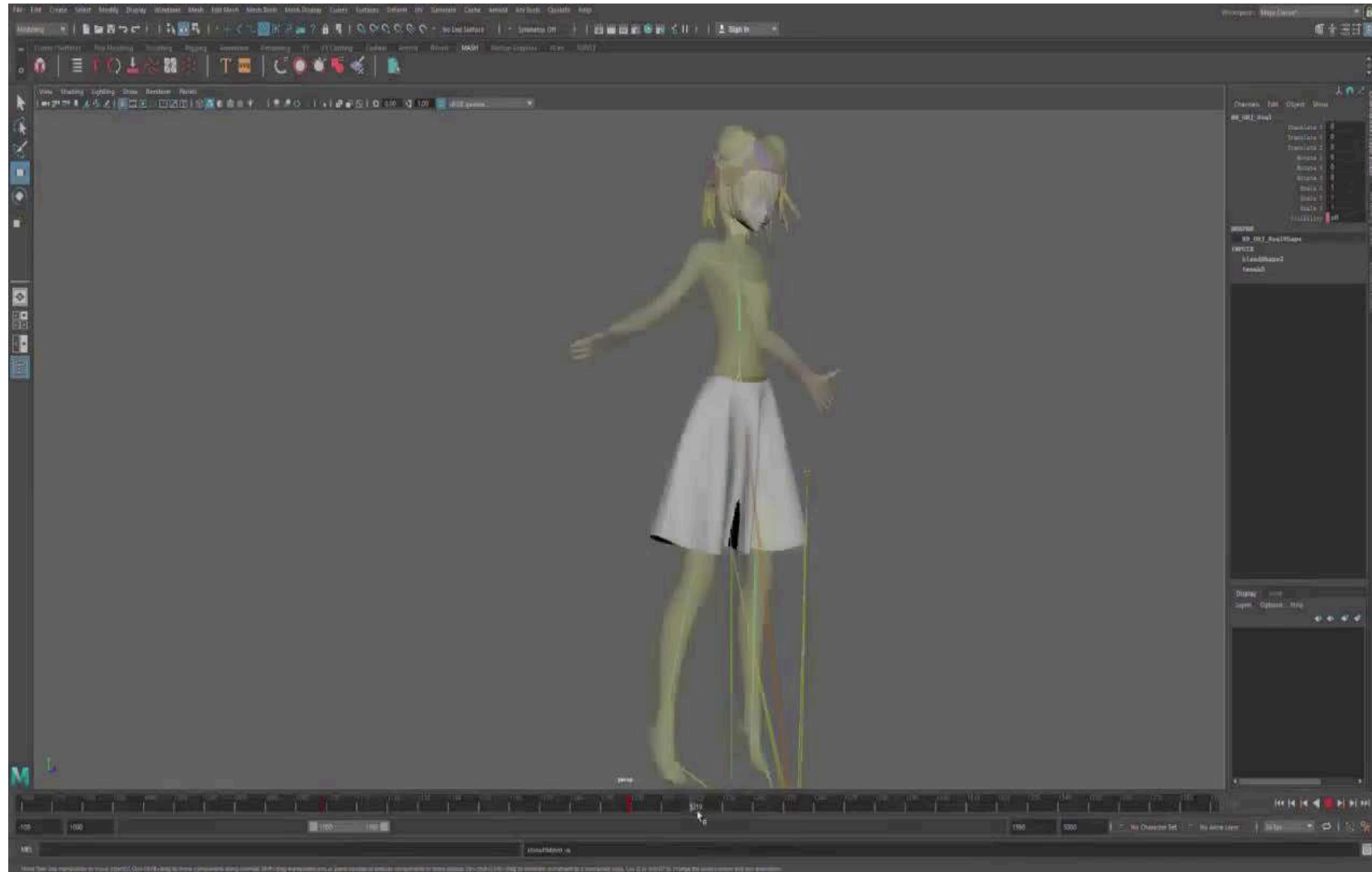
Free editing



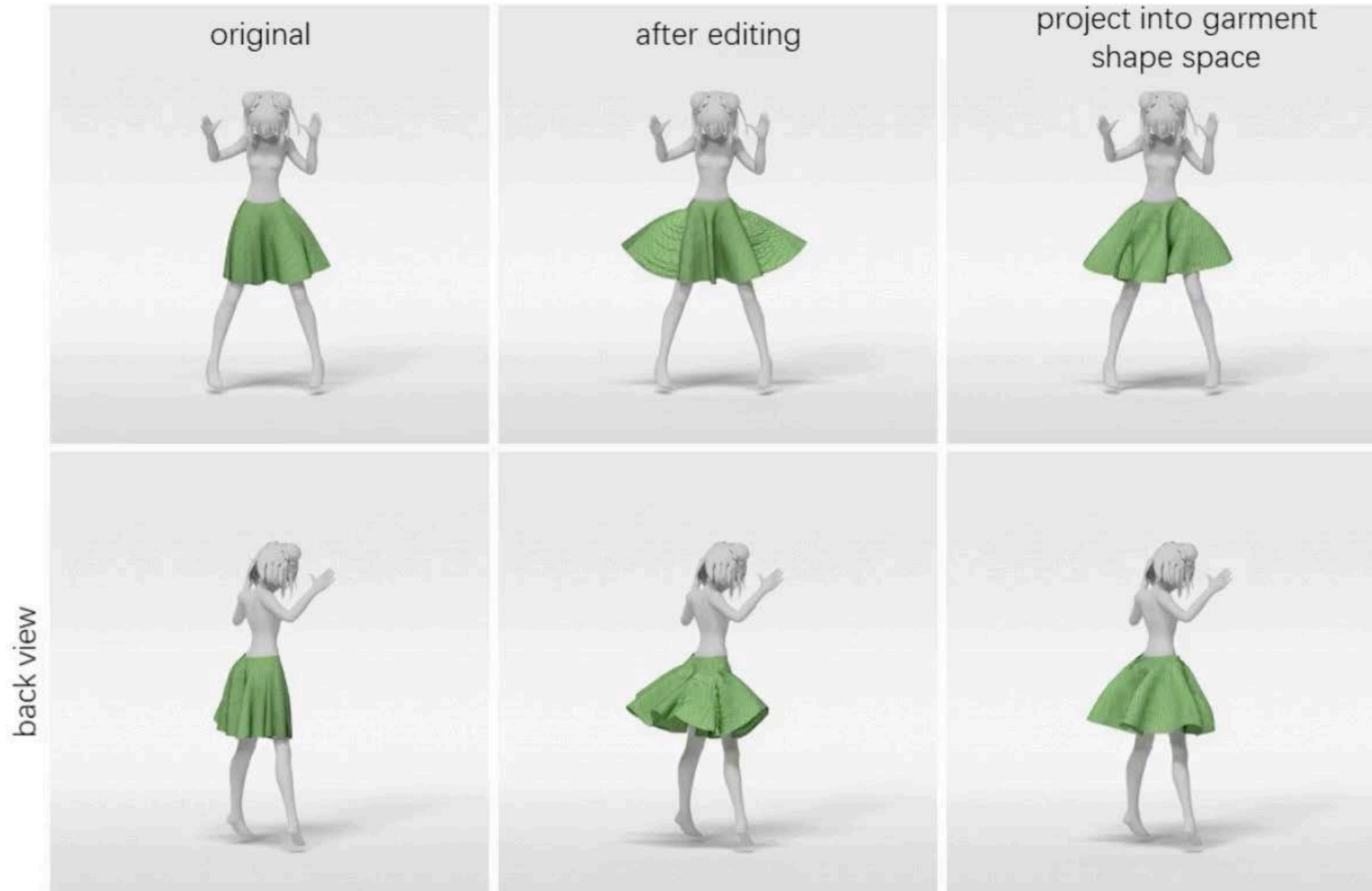
Free editing



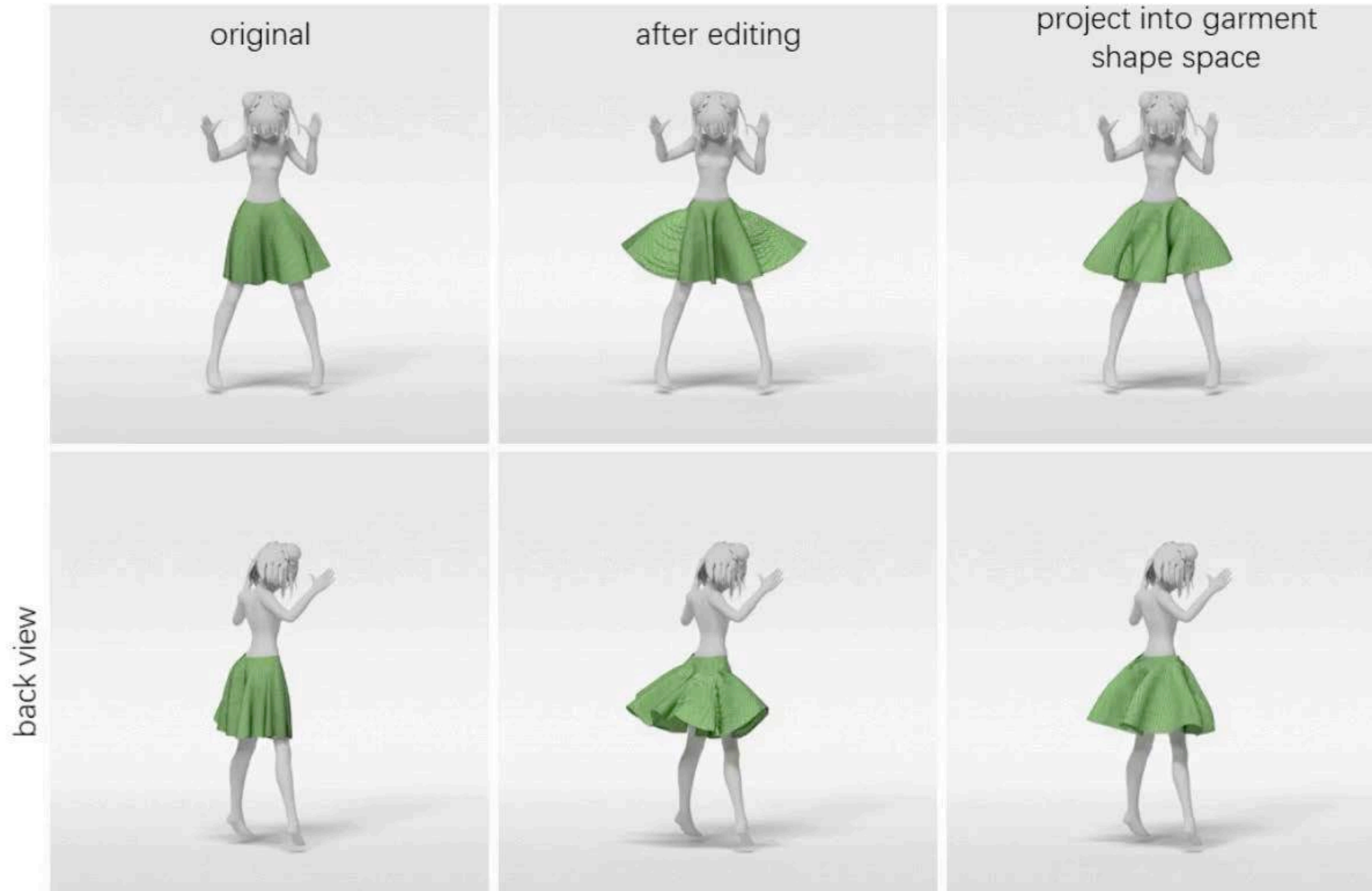
Free editing



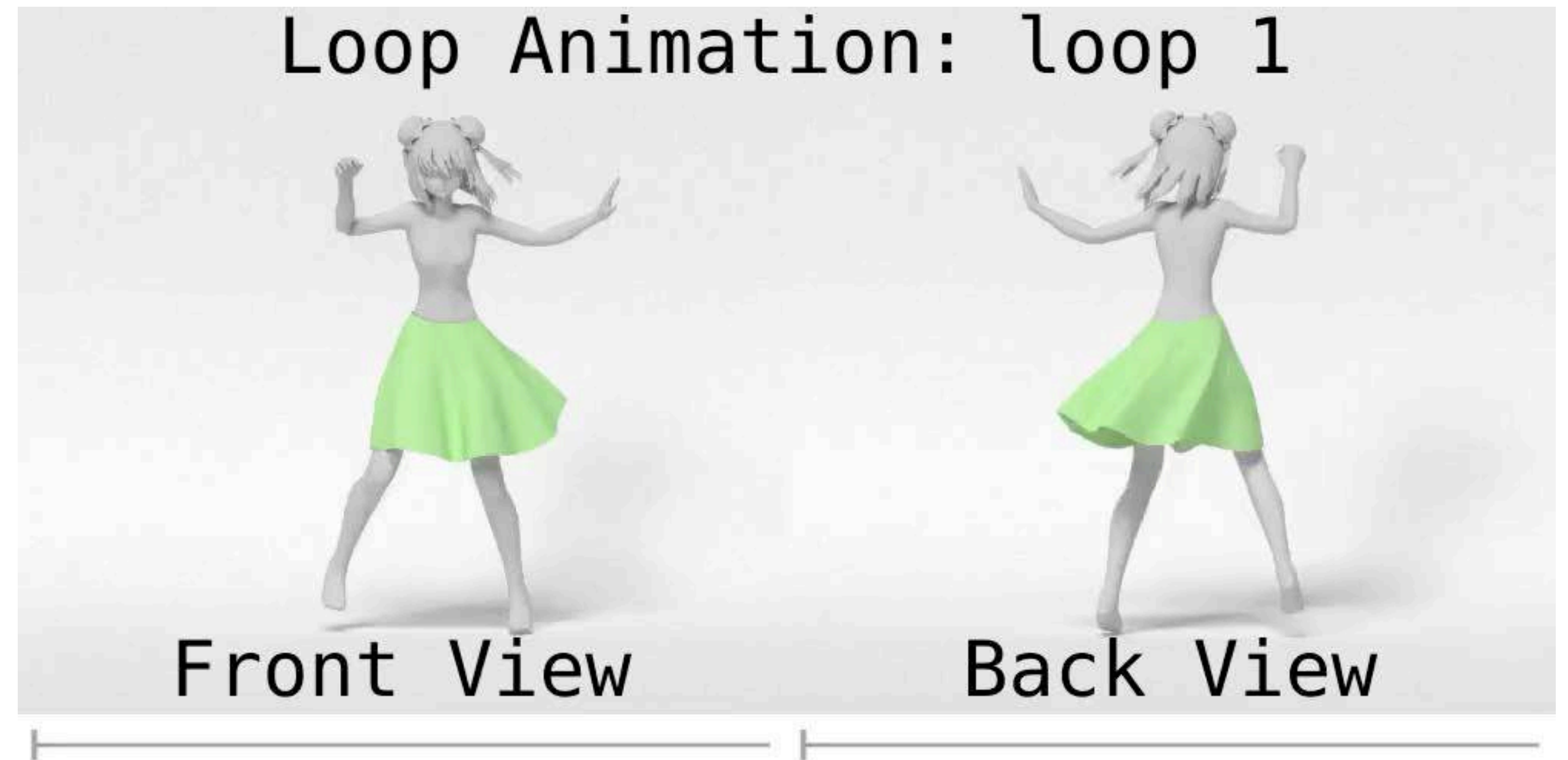
Free editing



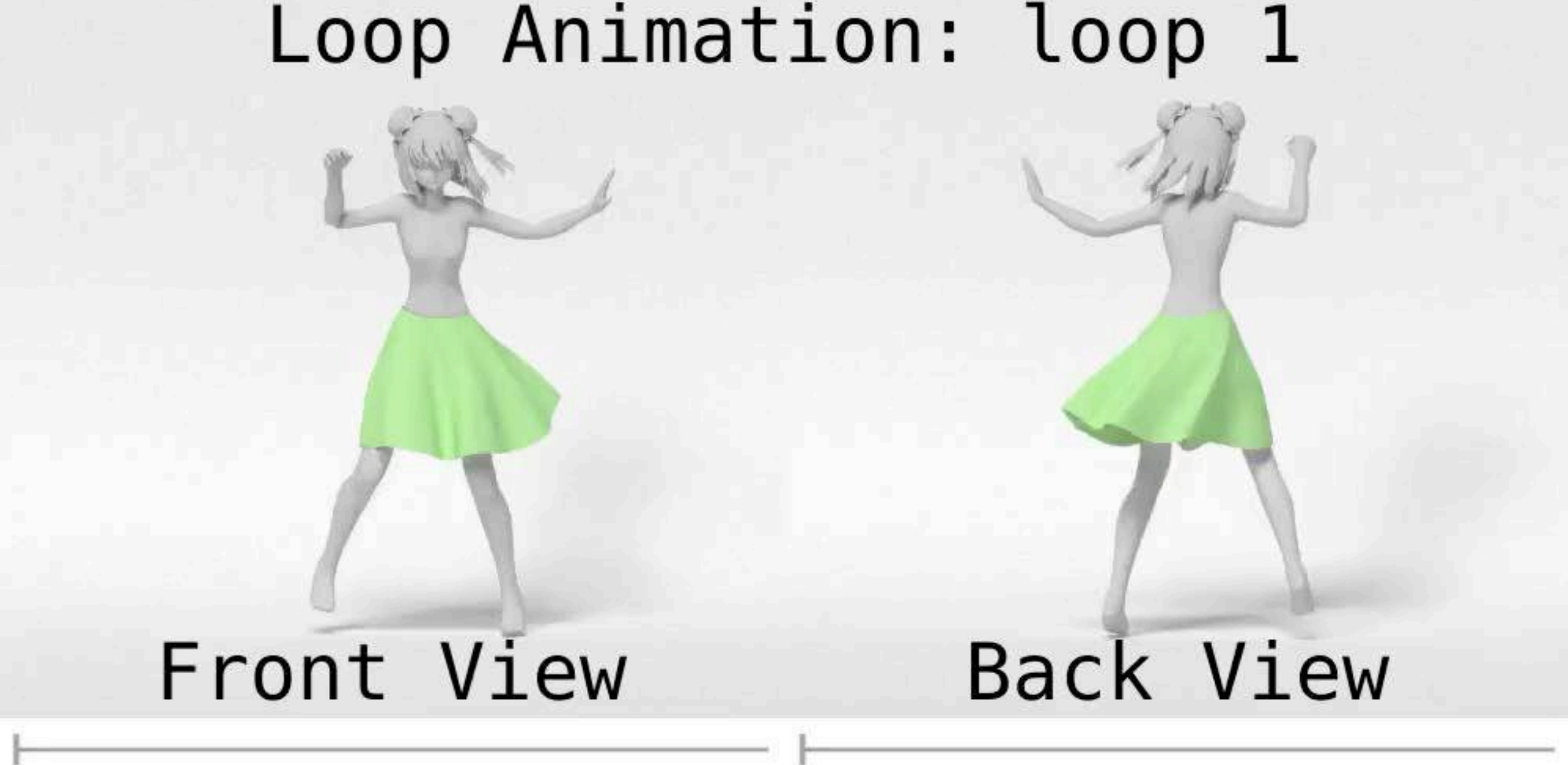
Free editing



Other applications

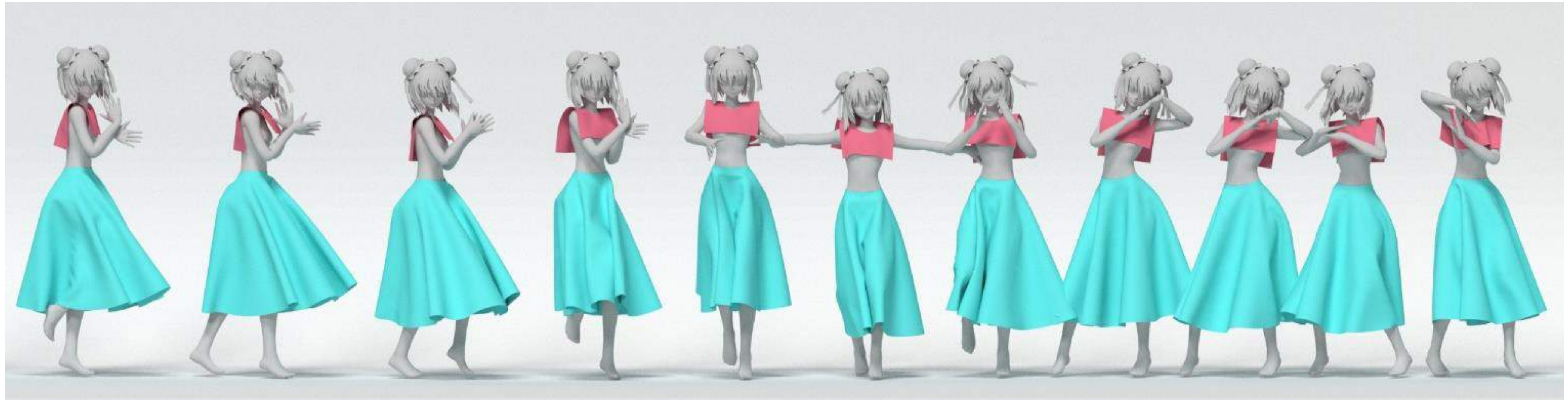


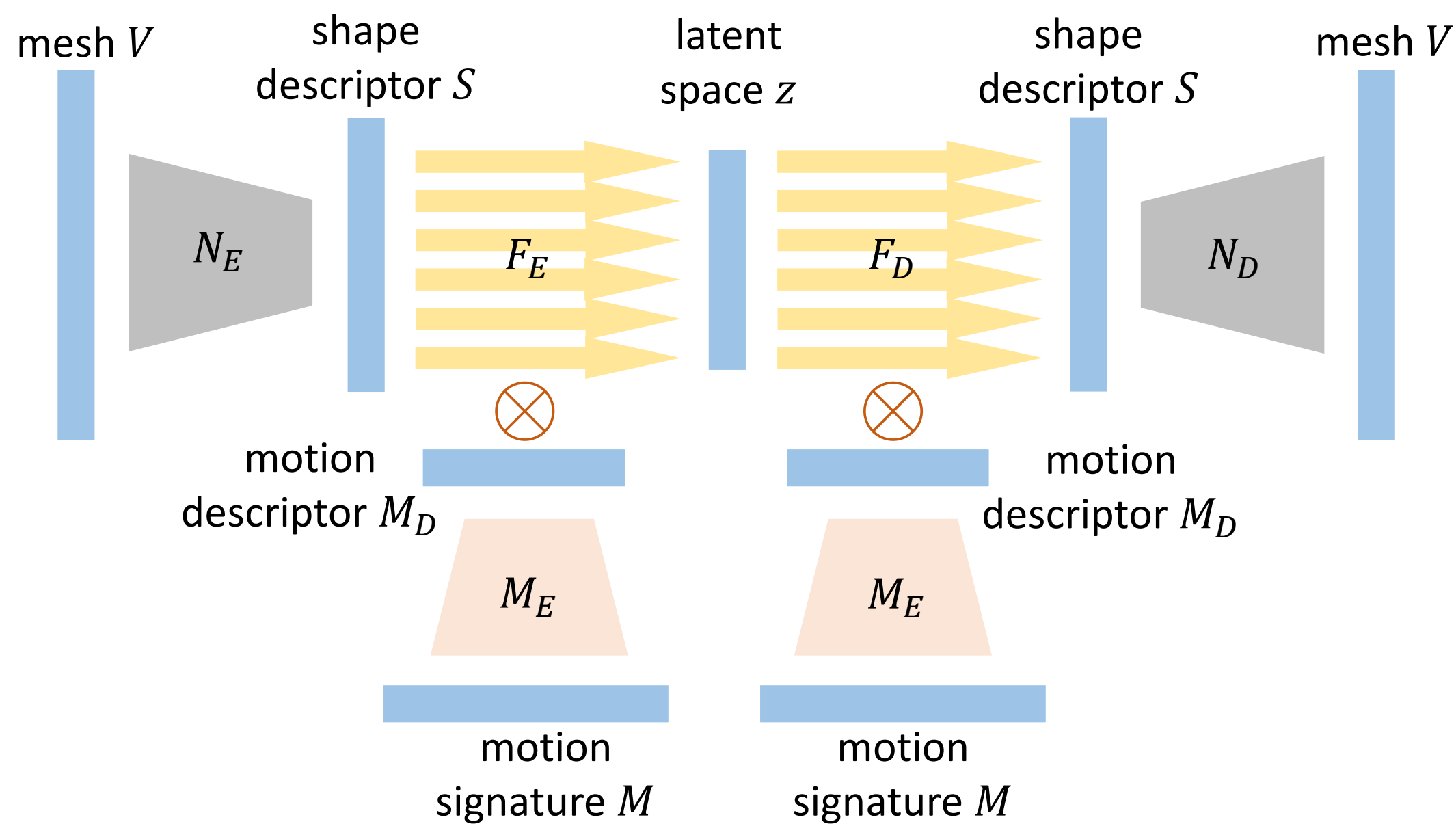
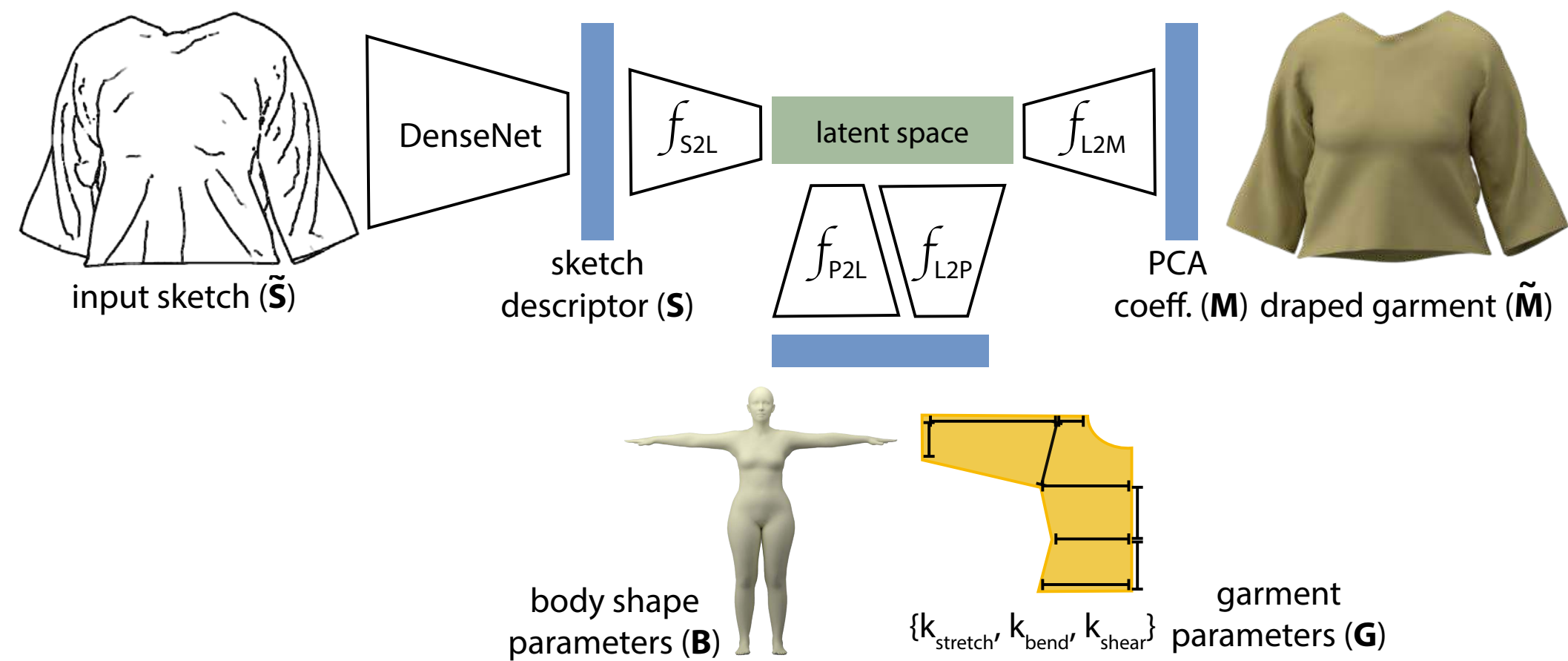
Other applications



Limitation & Future work

- Unicode for different types of garment





Subspace Neural Physics: Fast Data-Driven Interactive Simulation. [Holden et al. 2019]

Ground Truth \mathbf{Z}

Prediction \mathbf{Z}^*

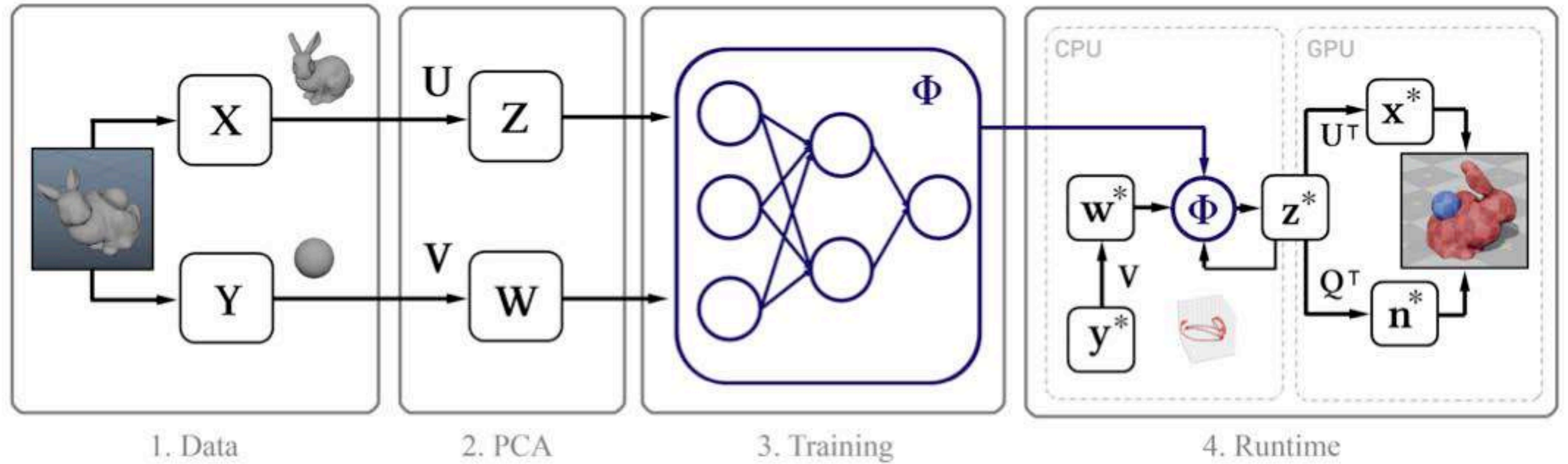
Velocity Projection $\bar{\mathbf{Z}}$

Network Correction Φ



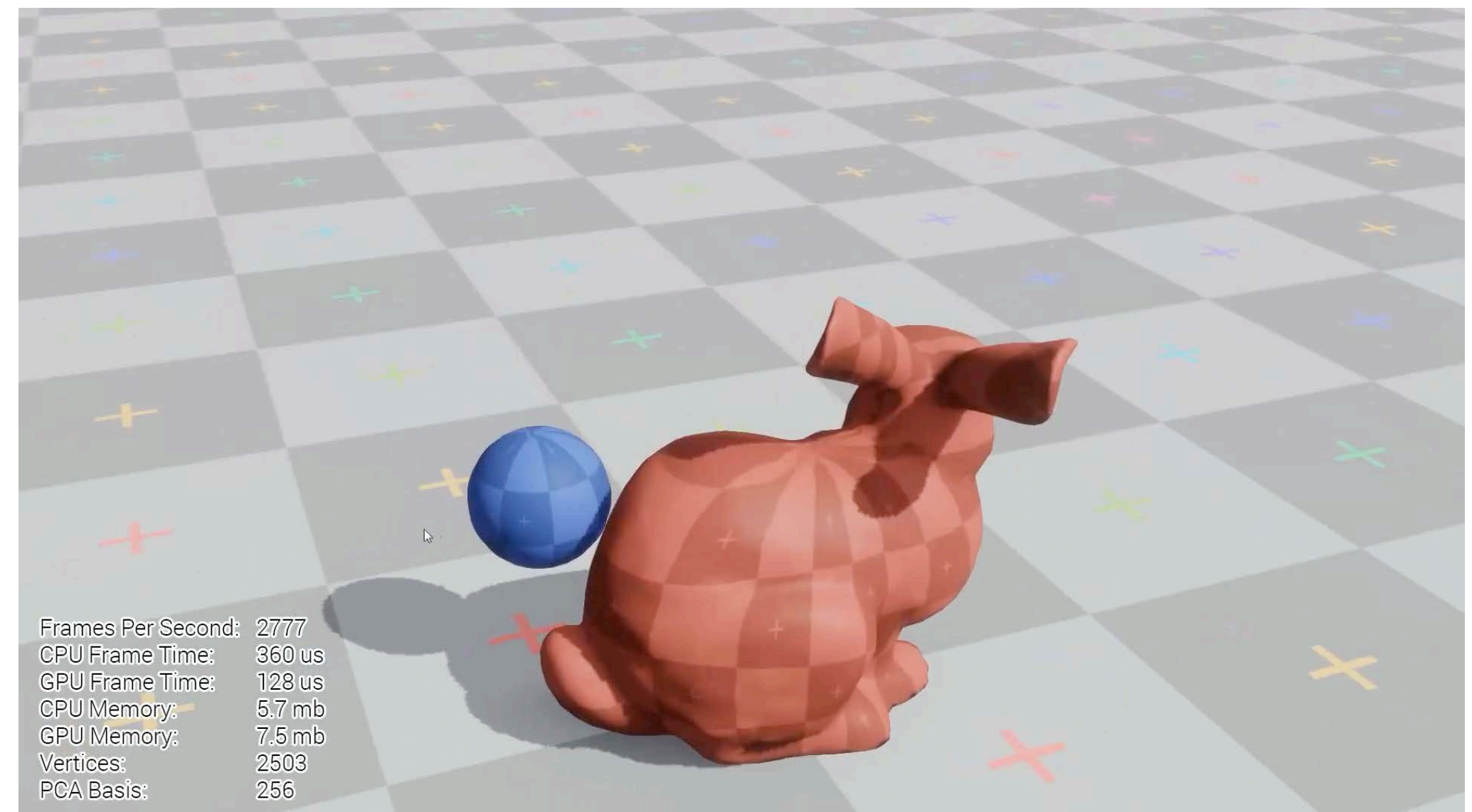
$$\bar{\mathbf{z}}_t = \alpha \odot \mathbf{z}_{t-1} + \beta \odot (\mathbf{z}_{t-1} - \mathbf{z}_{t-2}),$$

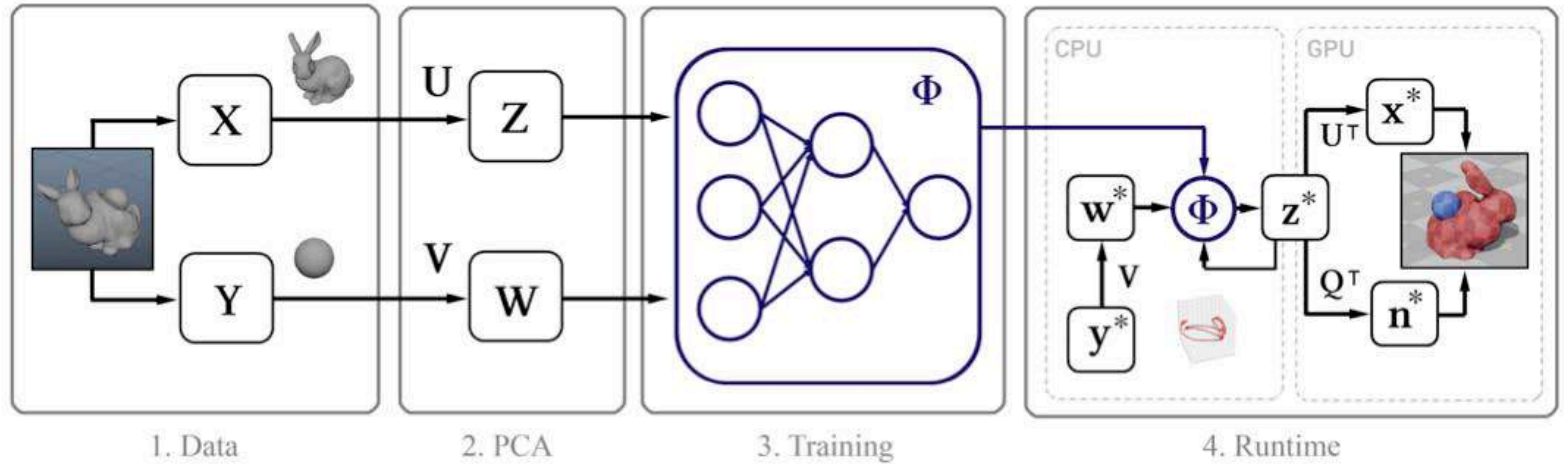
$$\mathbf{z}_t = \bar{\mathbf{z}}_t + \Phi \left(\left[\bar{\mathbf{z}}_t \quad \mathbf{z}_{t-1} \quad \mathbf{w}_t \right]^T \right)$$



$$\bar{\mathbf{z}}_t = \boldsymbol{\alpha} \odot \mathbf{z}_{t-1} + \boldsymbol{\beta} \odot (\mathbf{z}_{t-1} - \mathbf{z}_{t-2}),$$

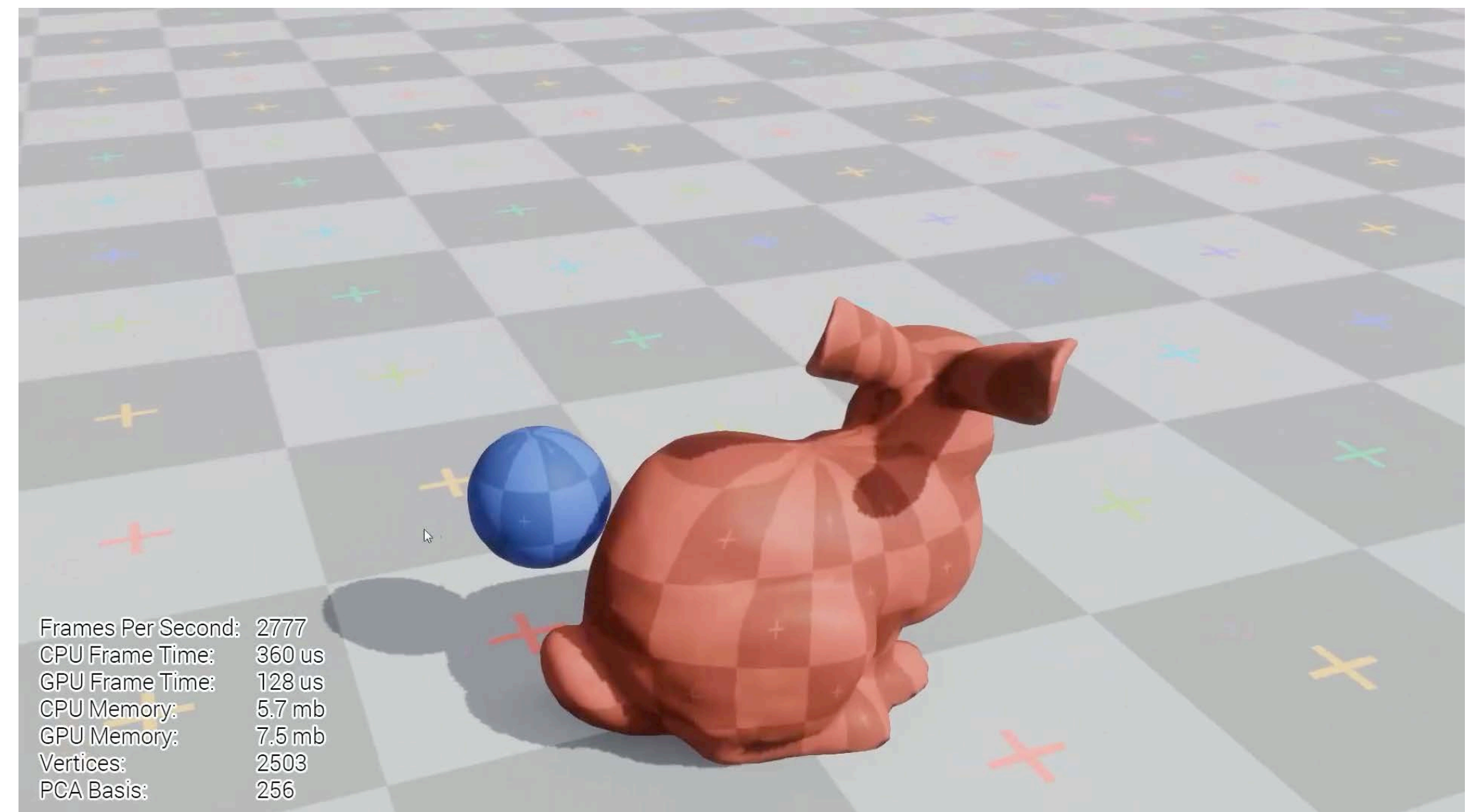
$$\mathbf{z}_t = \bar{\mathbf{z}}_t + \Phi \left(\left[\bar{\mathbf{z}}_t \quad \mathbf{z}_{t-1} \quad \mathbf{w}_t \right]^T \right)$$





$$\bar{\mathbf{z}}_t = \boldsymbol{\alpha} \odot \mathbf{z}_{t-1} + \boldsymbol{\beta} \odot (\mathbf{z}_{t-1} - \mathbf{z}_{t-2}),$$

$$\mathbf{z}_t = \bar{\mathbf{z}}_t + \Phi \left(\left[\bar{\mathbf{z}}_t \quad \mathbf{z}_{t-1} \quad \mathbf{w}_t \right]^T \right)$$



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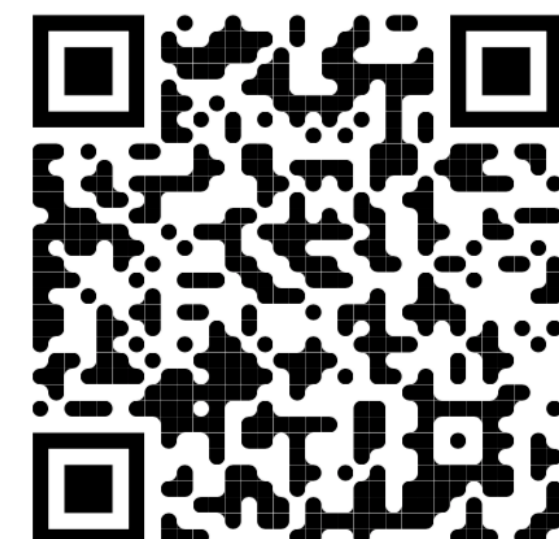
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Thank You