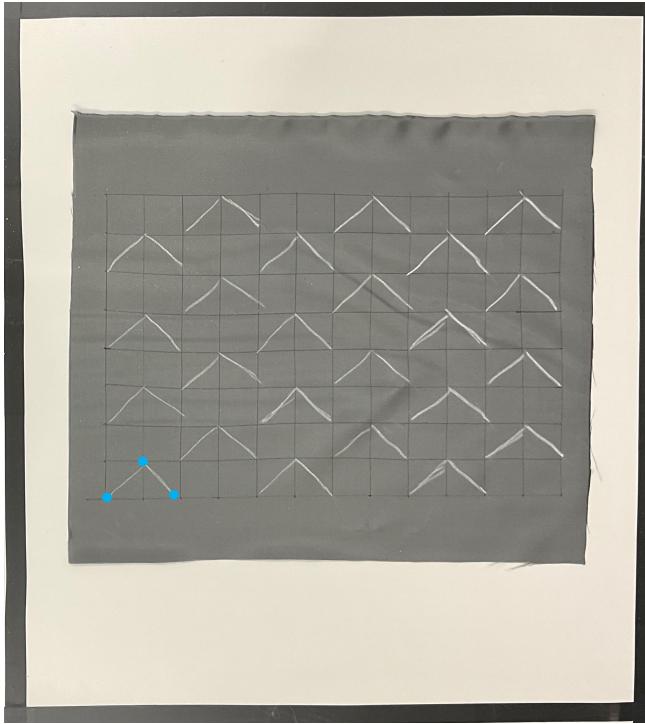


# Fabric Tessellation: Realizing Freeform Surfaces by Smocking

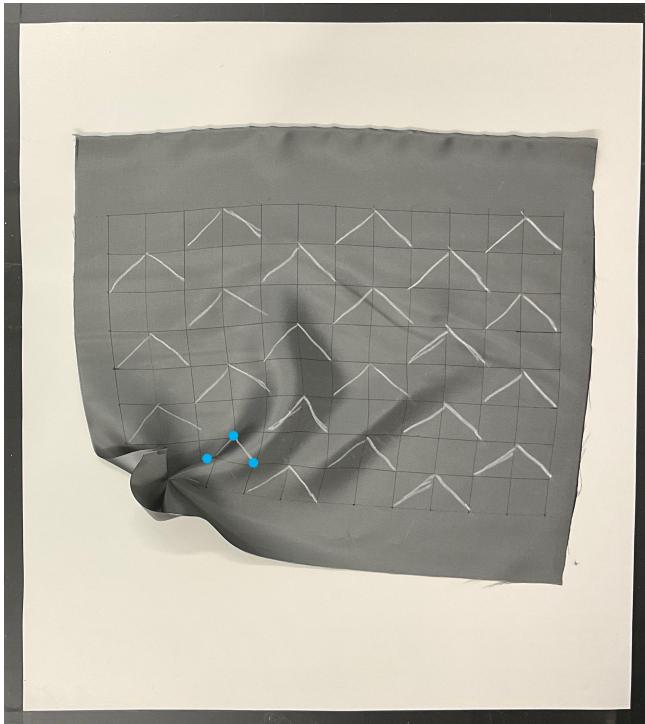
Aviv Segall, Jing Ren, Amir Vaxman,  
Olga Sorkine-Hornung



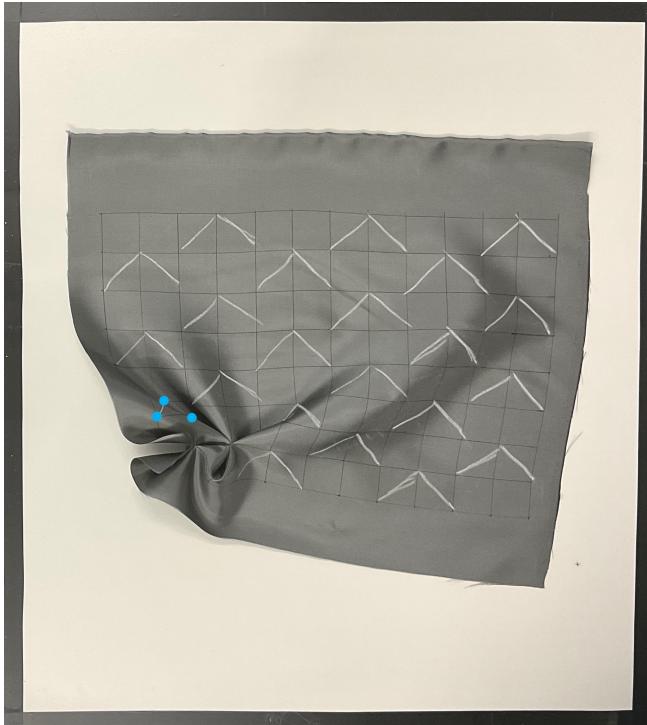
# What is smocking?



# What is smocking?



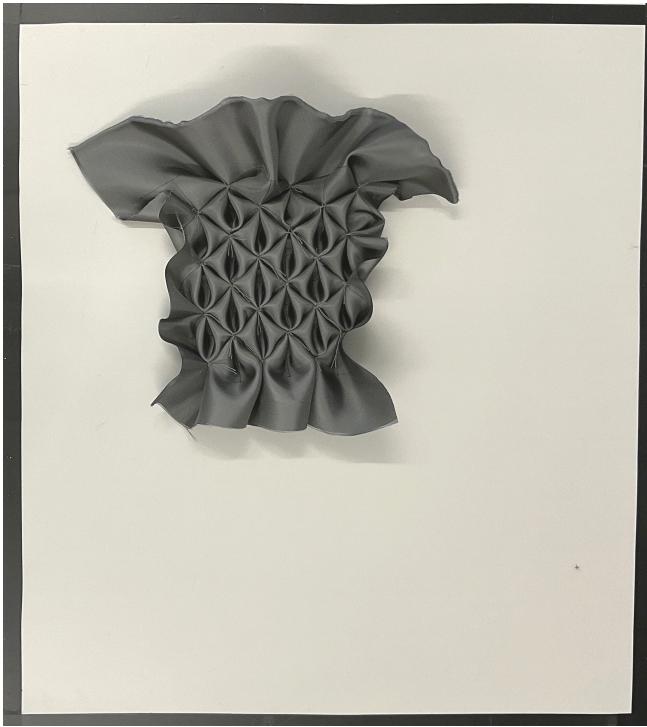
# What is smocking?



# What is smocking?



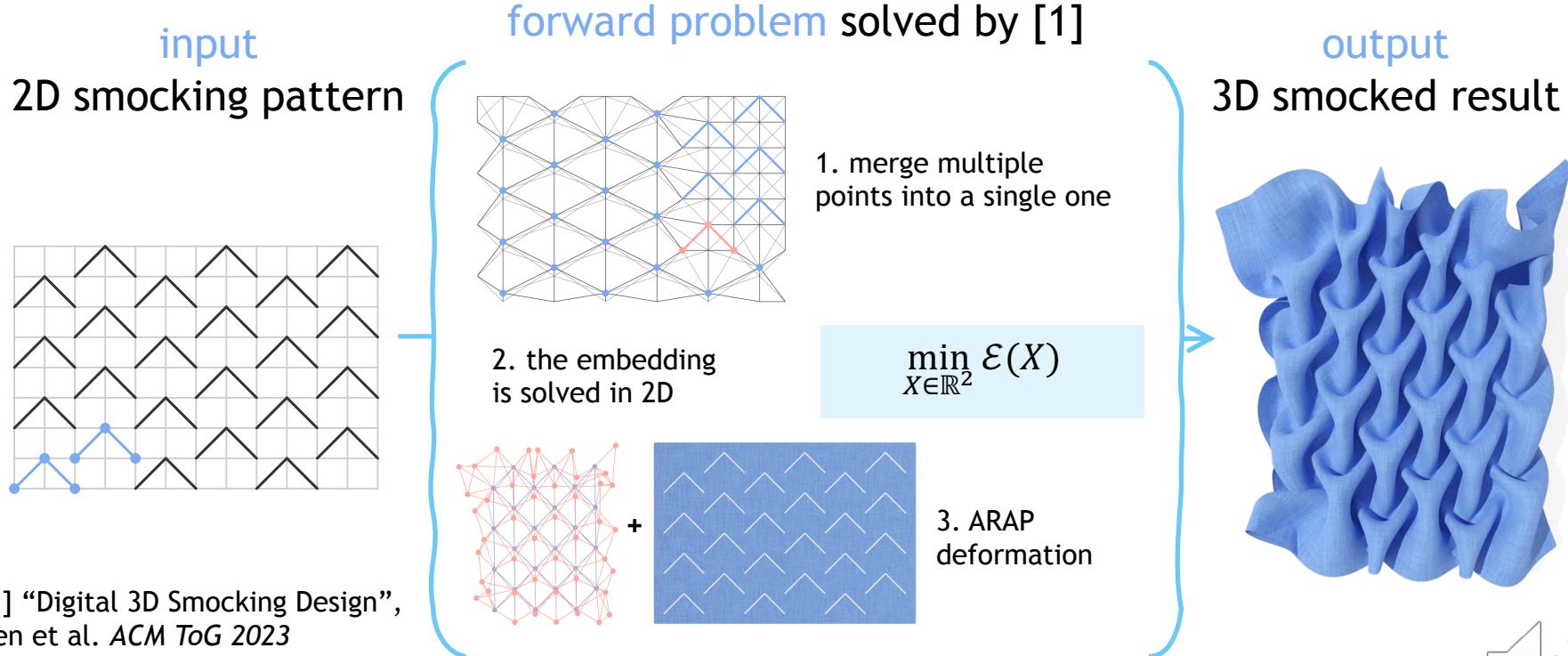
# What is smocking?



# Forward problem



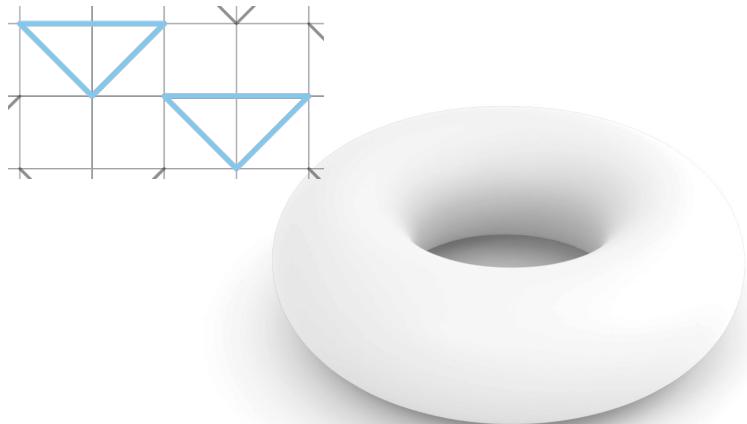
# Forward problem



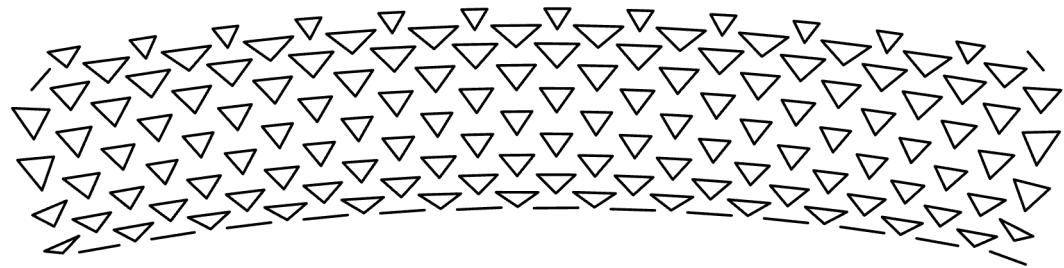
[1] "Digital 3D Smocking Design",  
Ren et al. ACM ToG 2023

# Inverse design for smocking

**input** 3D shape + smocking type



**output** modified smocking pattern



after  
fabrication

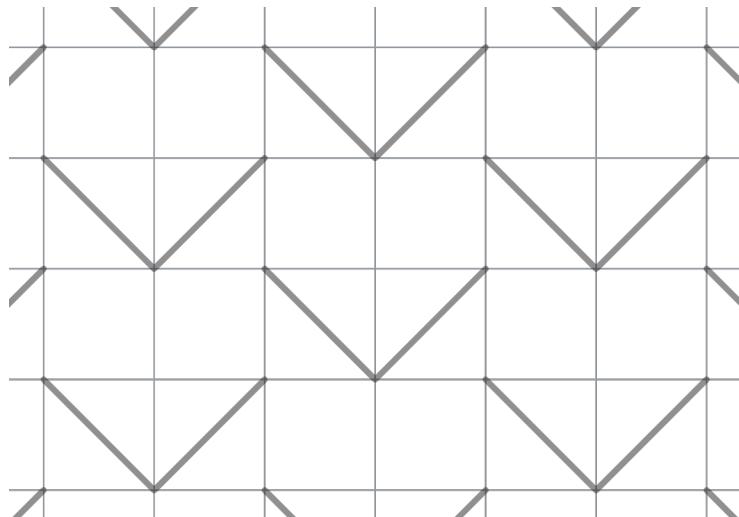


## requirements

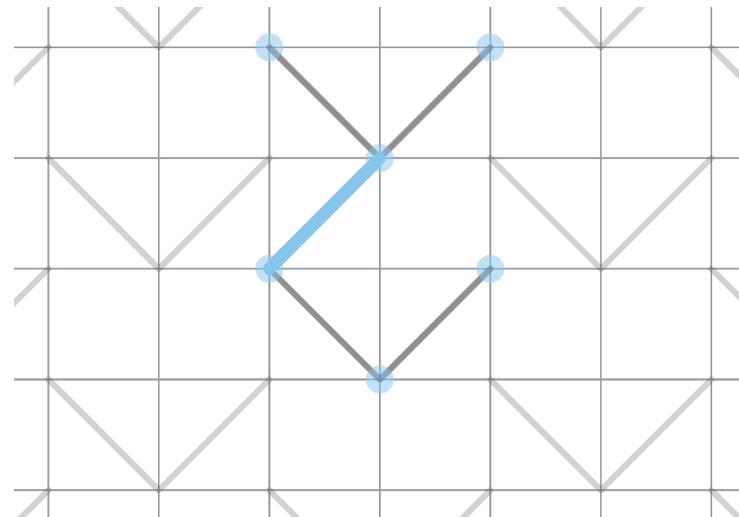
- ❖ approximate the input shape
- ❖ with nicely shaped pleats

# Methodology : extract tangram

smocking pattern



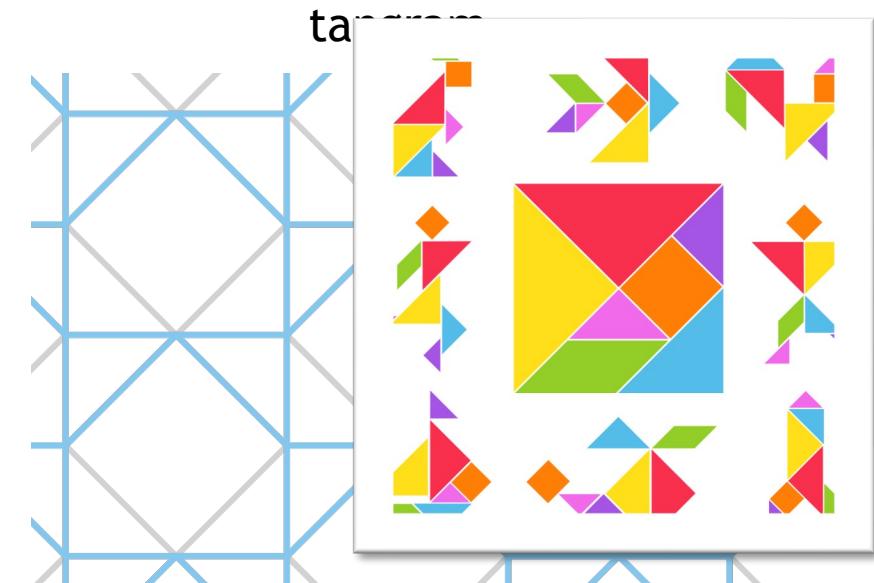
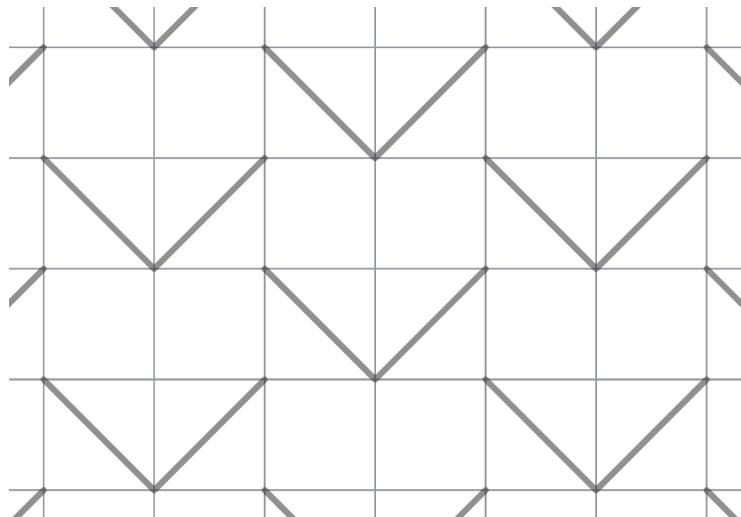
underlay edge



connecting two different  
stitching lines

# Methodology : extract tangram

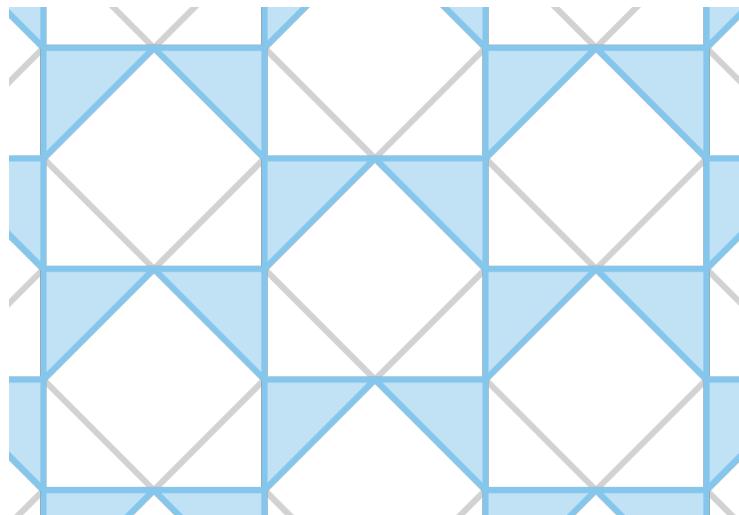
smocking pattern



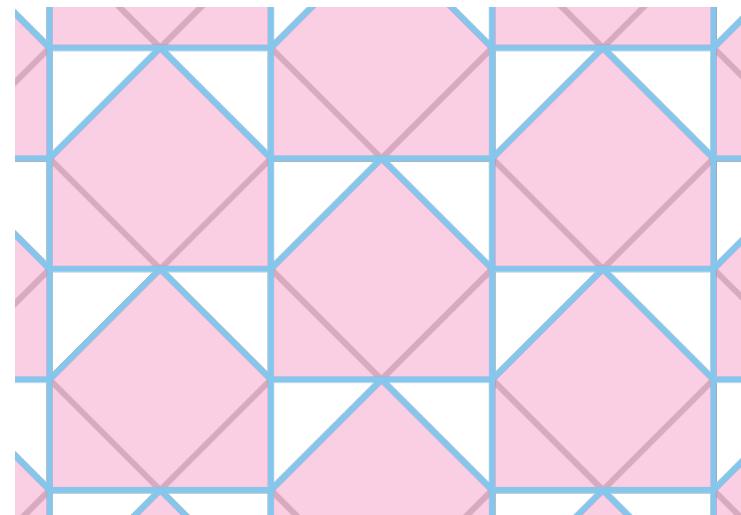
subgraph consisting of all  
underlay edges

# Methodology : extract tangram

underlay faces

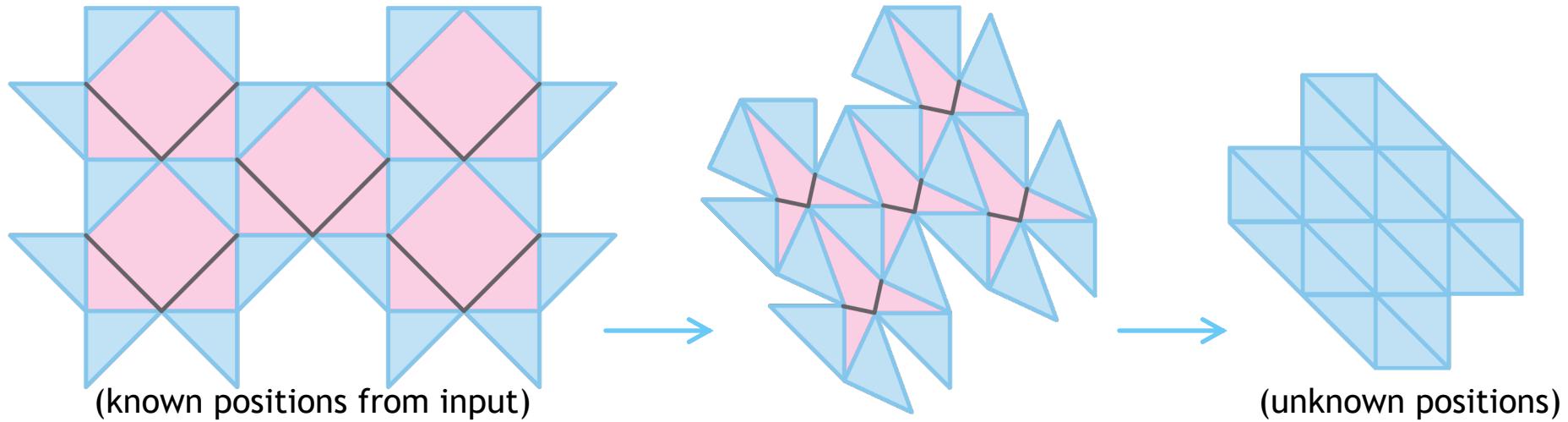


pleat faces

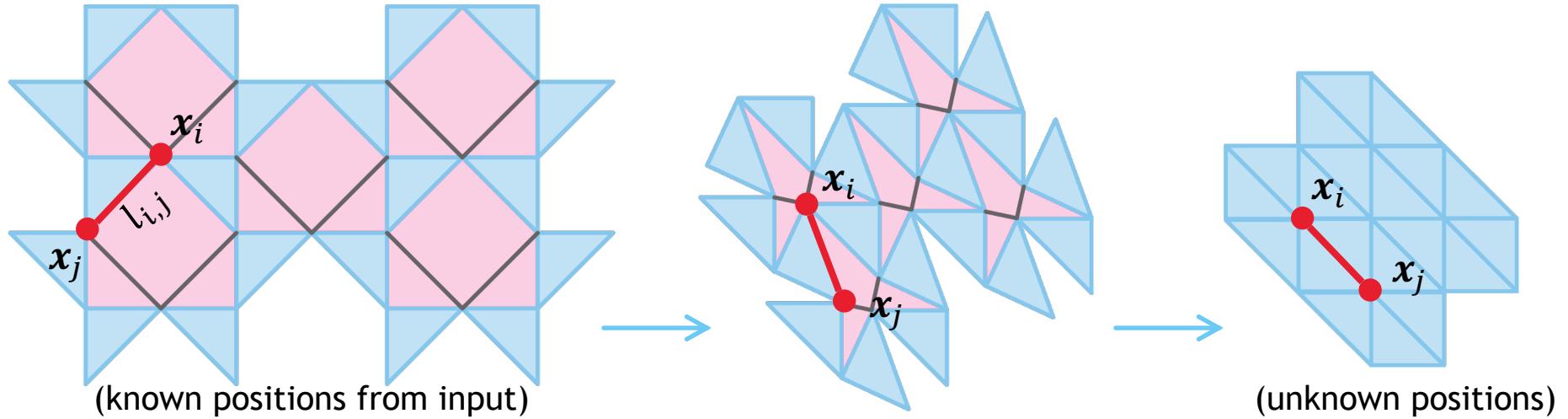


bounded regions that contain  
stitching lines

# Methodology : closing tangram

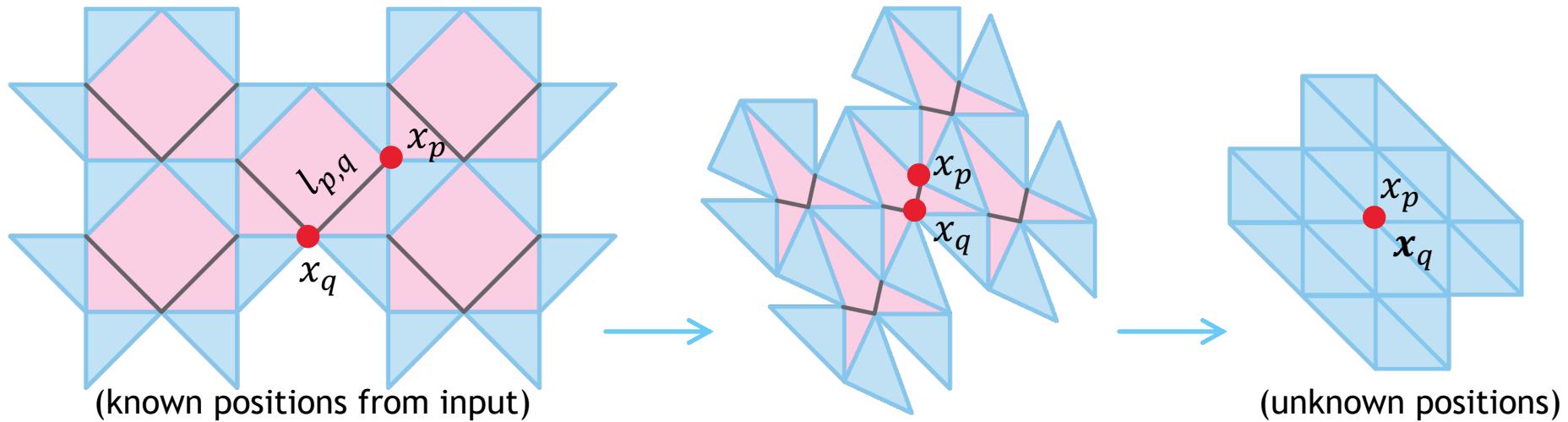


# Methodology : closing tangram



$$E_{\text{rigid}} = \sum_{(i,j) \in \mathcal{E}_r} (\|x_i - x_j\| - l_{i,j})^2$$

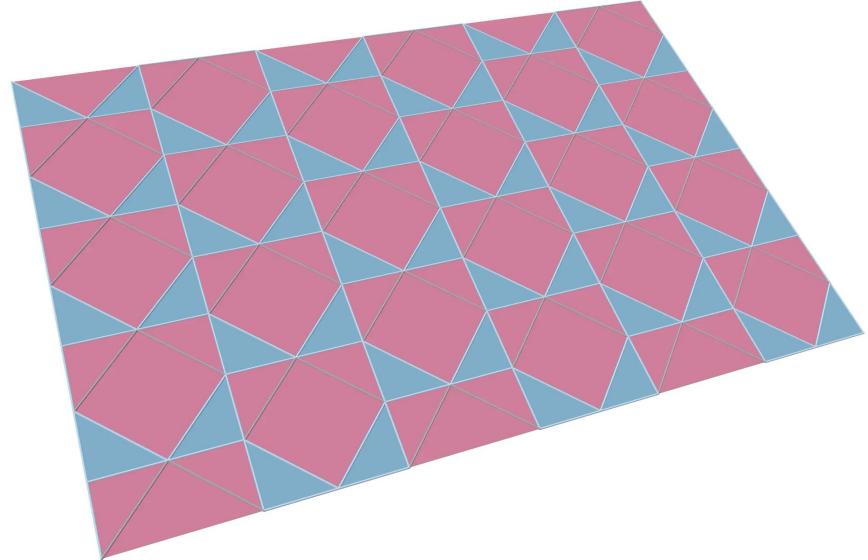
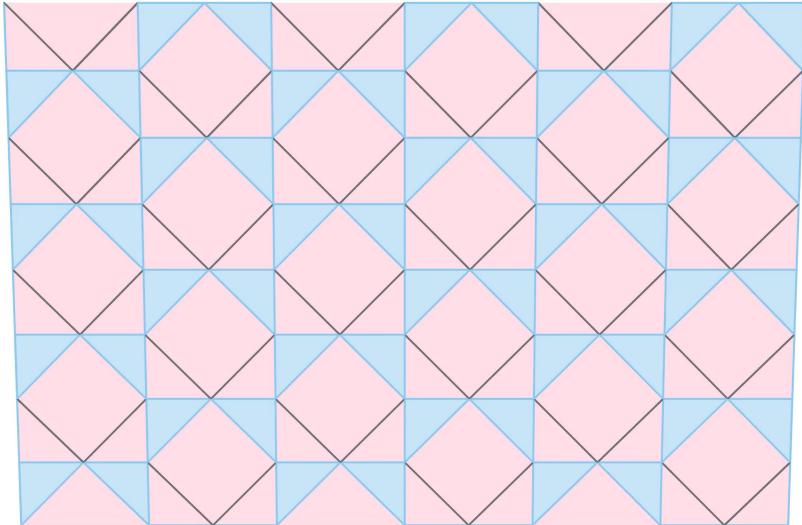
# Methodology : closing tangram



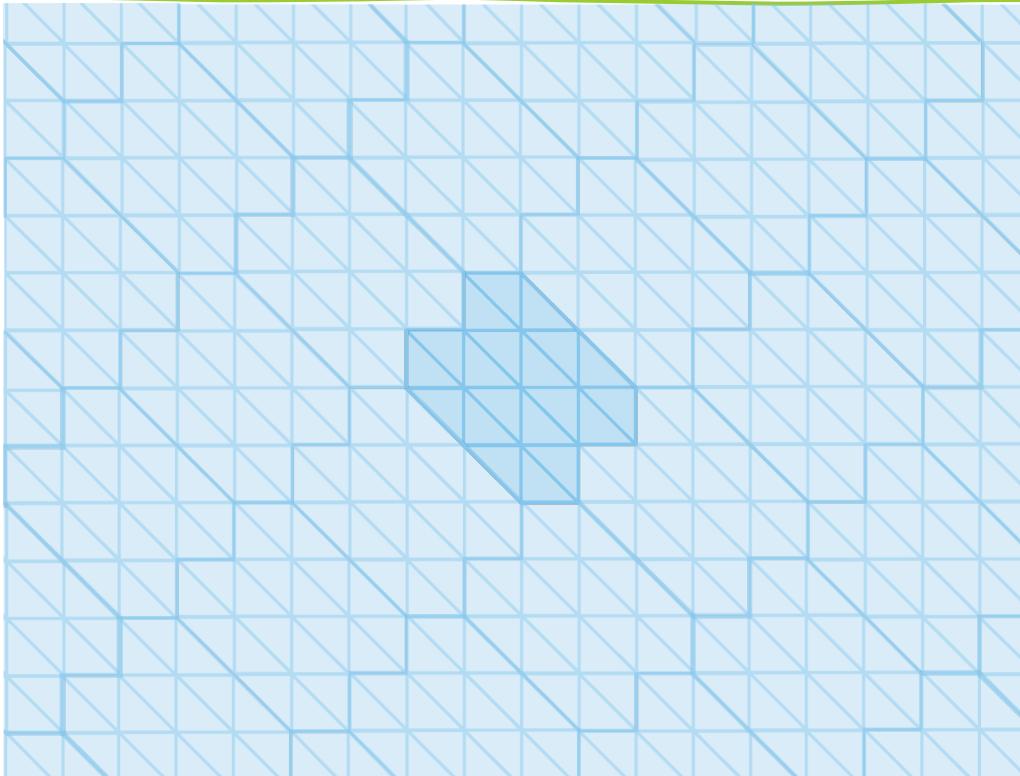
$$E_{\text{rigid}} = \sum_{(i,j) \in \mathcal{E}_r} (\|x_i - x_j\| - l_{i,j})^2$$

$$E_{\text{stitch}} = \sum_{(p,q) \in \mathcal{L}} (\|x_p - x_q\| - \eta l_{p,q})^2$$

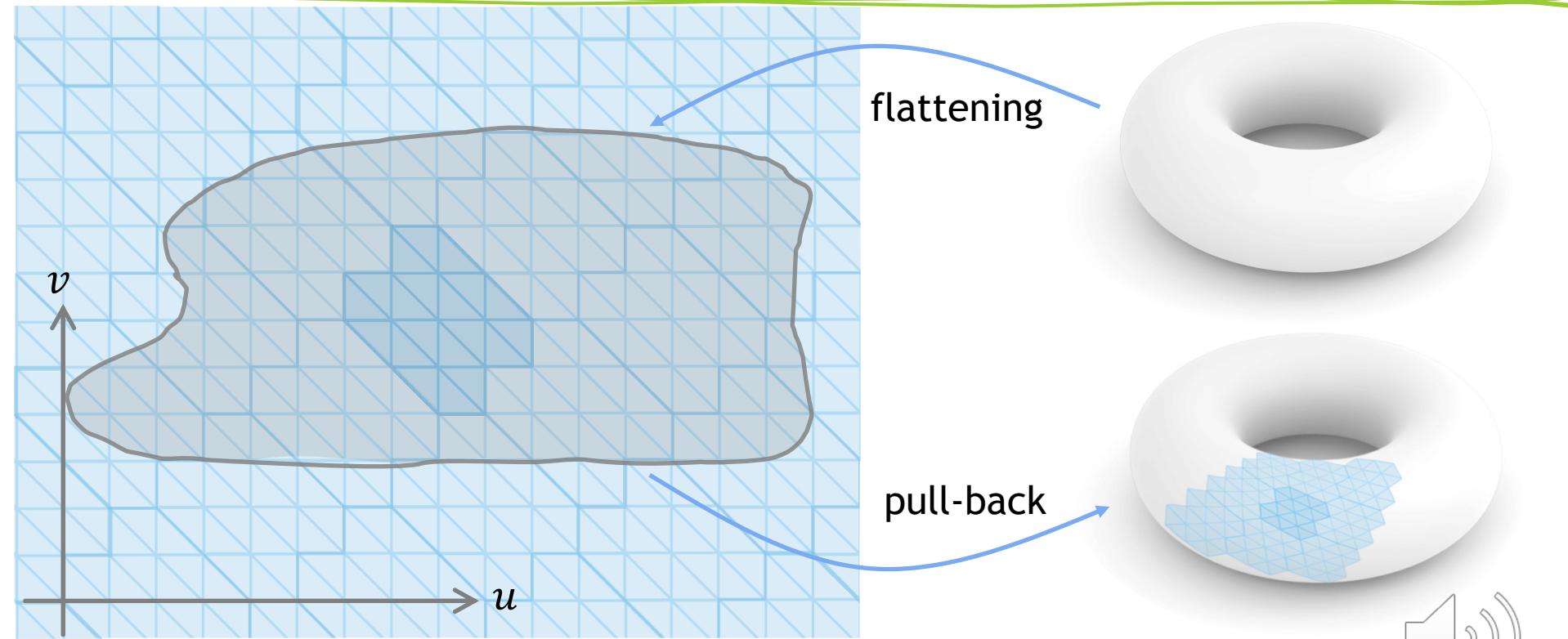
# Methodology : closing tangram



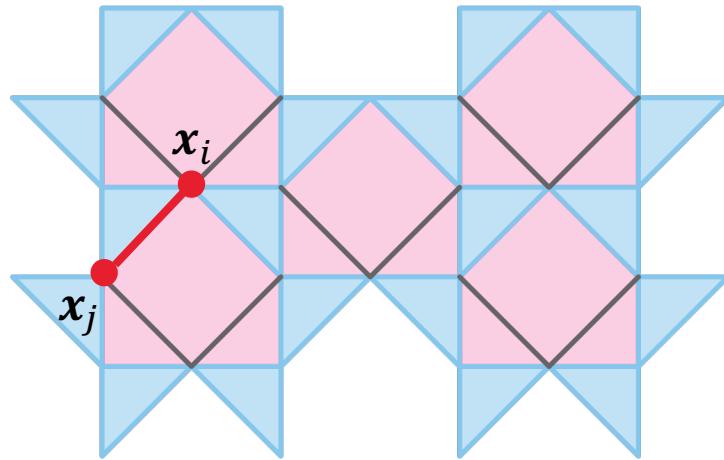
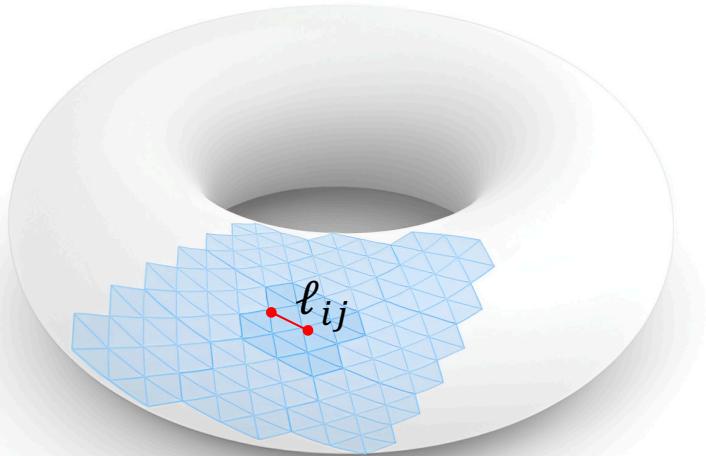
# Methodology: plane tiling



# Methodology: pull-back

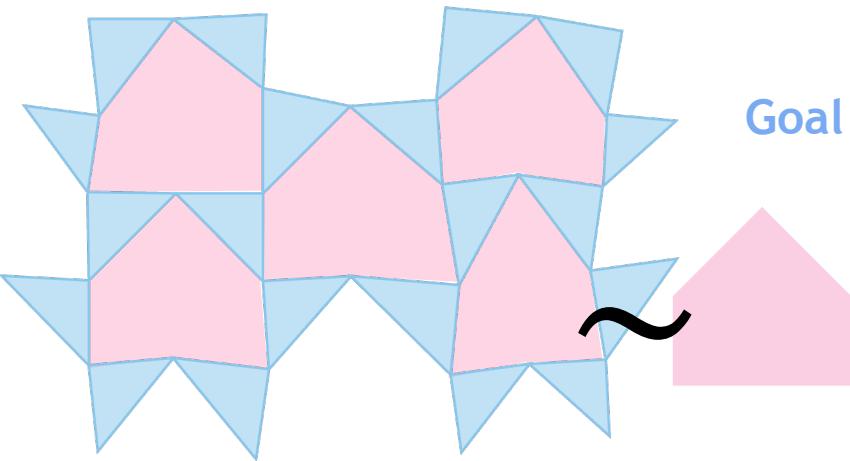


# Methodology: optimize Tangram



$$E_{\text{shape}}(X) = \sum_{(i,j) \in \mathcal{E}_u} \left( \frac{\|x_i - x_j\|}{\ell_{ij}} - 1 \right)^2$$

# Methodology : pleat regularity

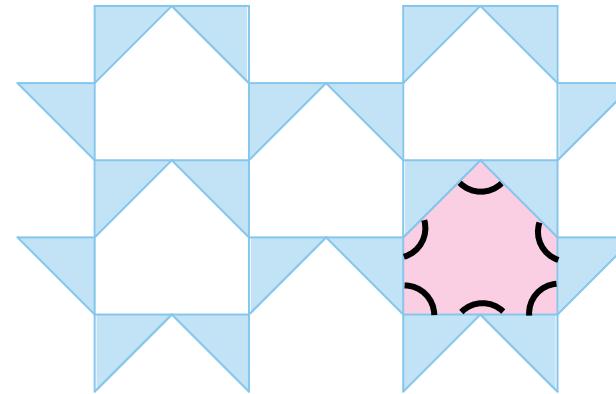
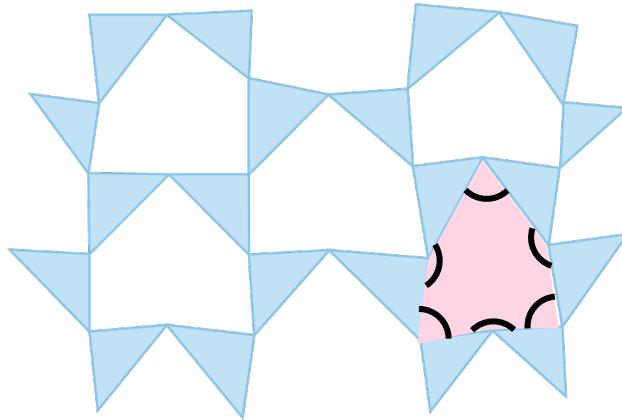


Goal the pleats are regular

Output: modified pattern

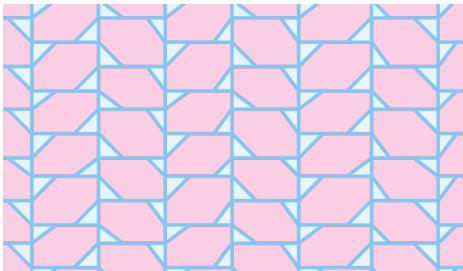


# Methodology : pleat regularity



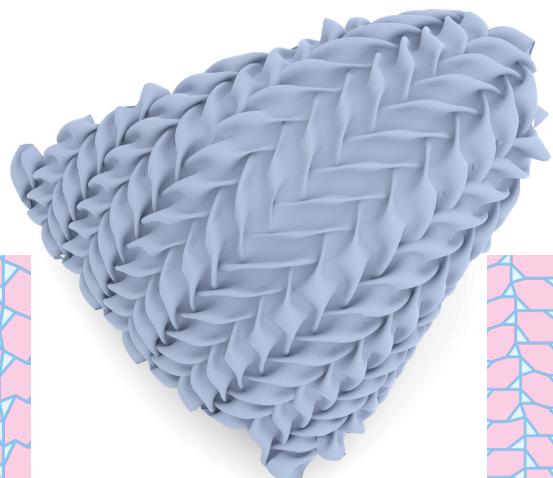
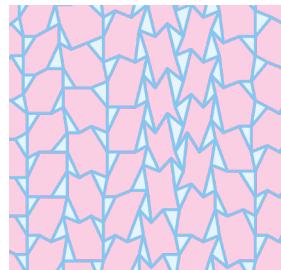
$$E_{\text{pleat}}(X) = \sum_{(i,j),(j,k) \in F_p} \left( \frac{\angle(x_i, x_j, x_k) - \angle(\hat{x}_i, \hat{x}_j, \hat{x}_k)}{2\pi} \right)^2$$

# Methodology : pleat regularity

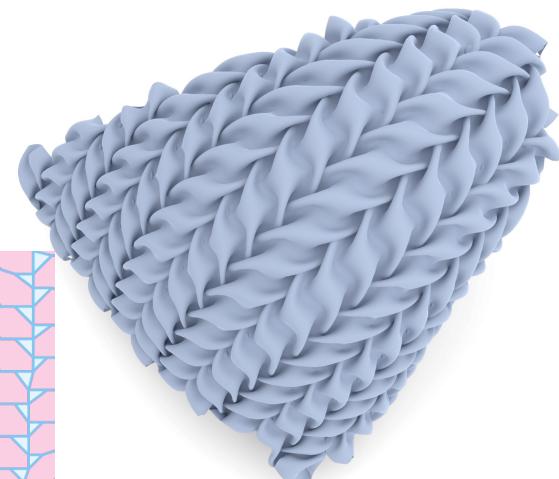
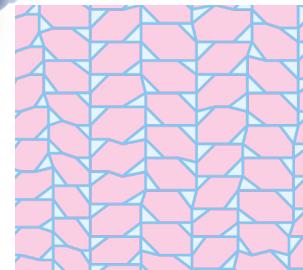


initial tangram

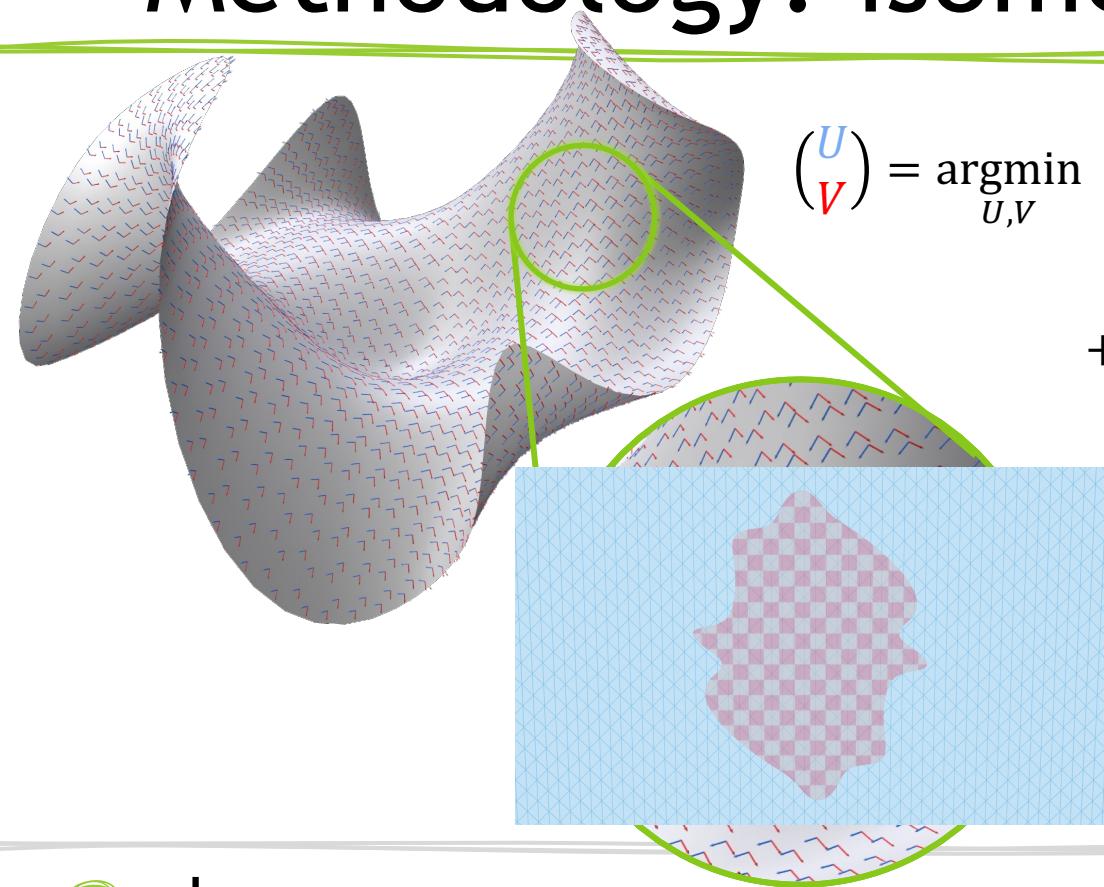
optimized tangram/result  
**without** pleat regularity



optimized tangram/result  
**with** pleat regularity

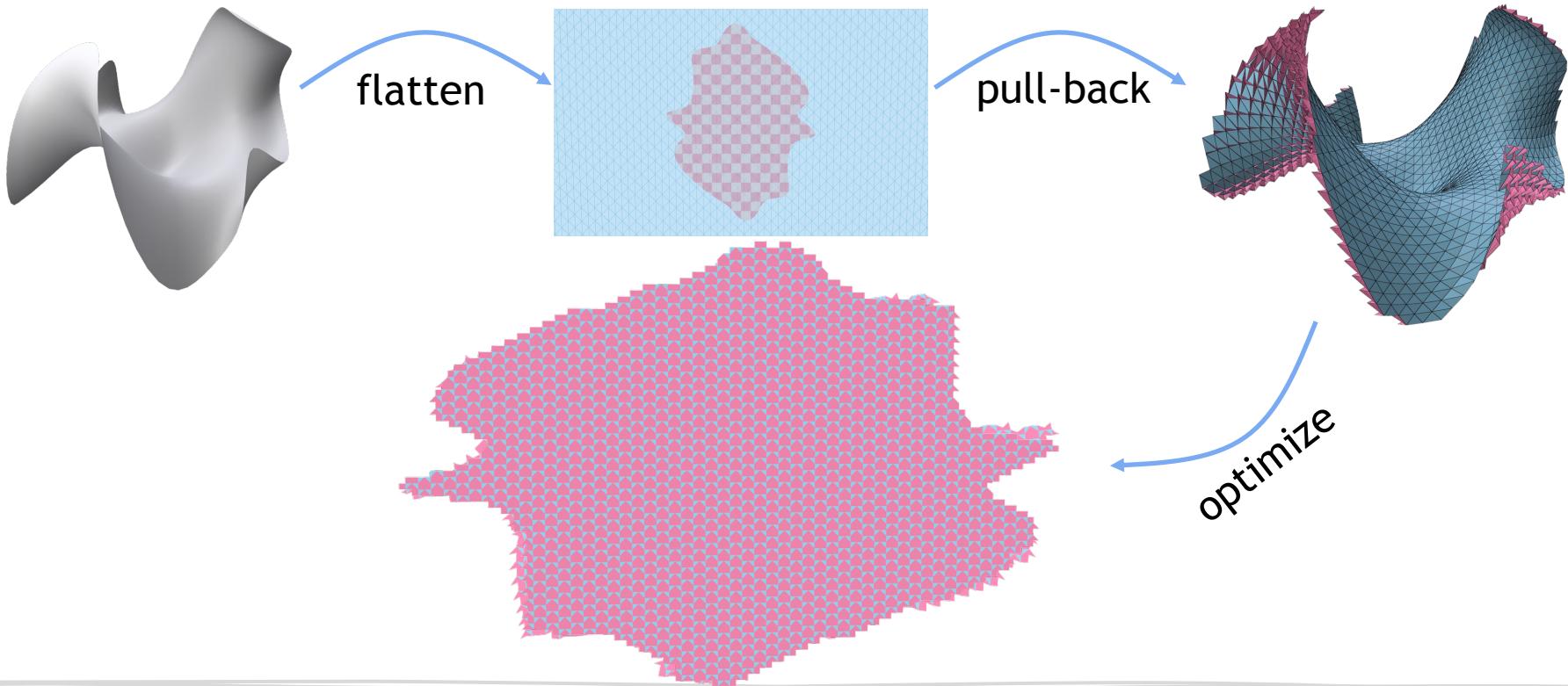


# Methodology: isometric flattening

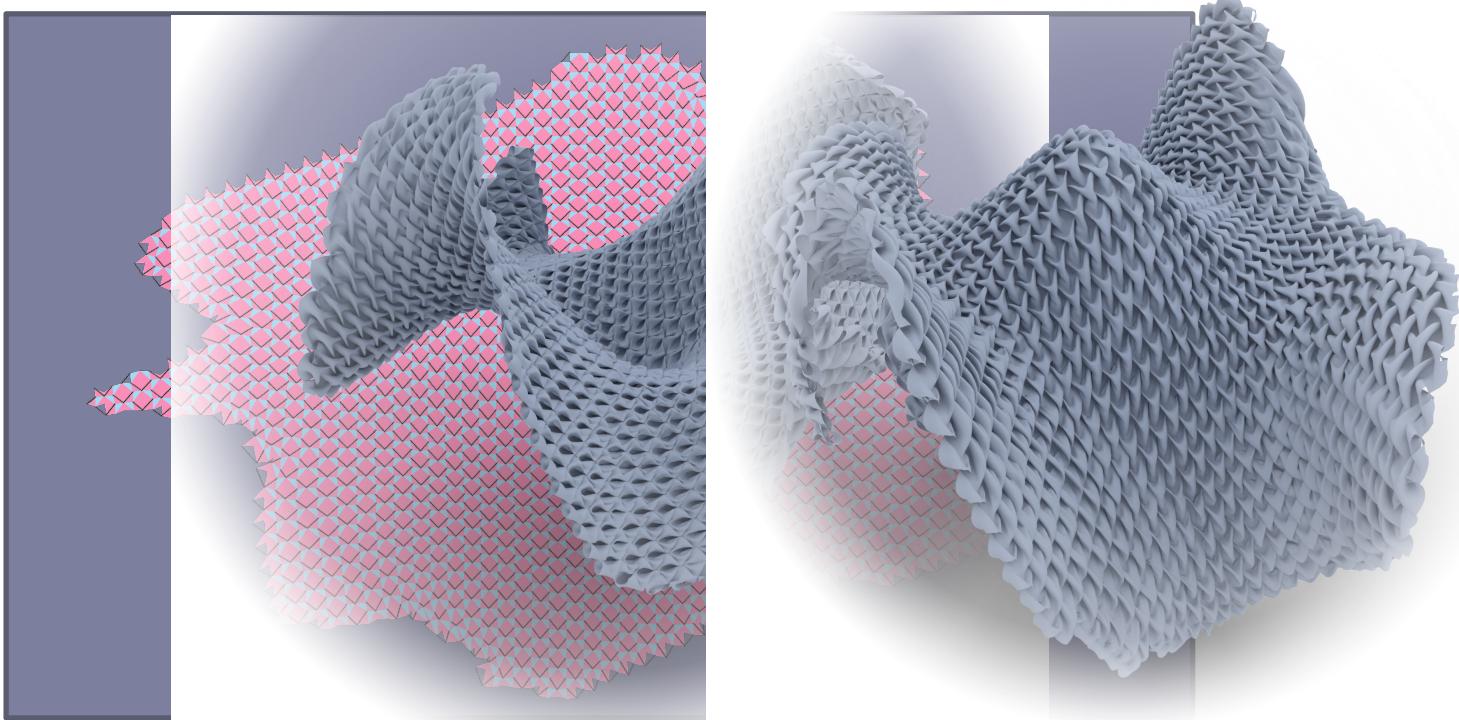


$$\begin{aligned} \begin{pmatrix} U \\ V \end{pmatrix} = \operatorname{argmin}_{U,V} \alpha \sum_f A_f ((|U(f)| - 1)^2 + (|V(f)| - 1)^2) \\ + \beta \sum_f A_f (V(f) - iU(f))^2 \\ s.t. \quad C \begin{pmatrix} U \\ V \end{pmatrix} = 0 \quad (\text{integrability}) \end{aligned}$$

# Methodology: recap

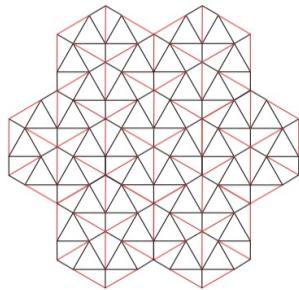


# Methodology: extract stitching

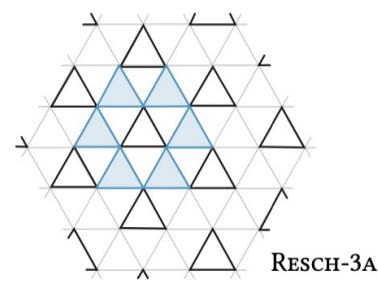


# Resch pattern for seamless smocking

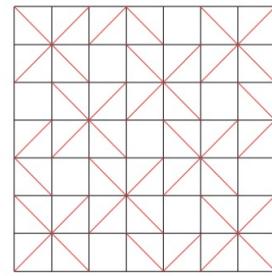
crease pattern



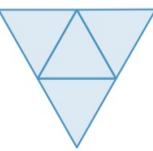
smocking pattern



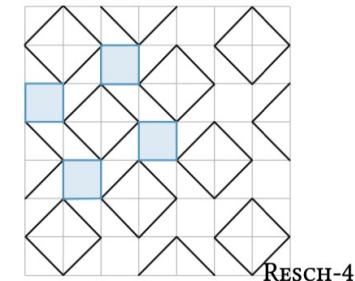
crease pattern



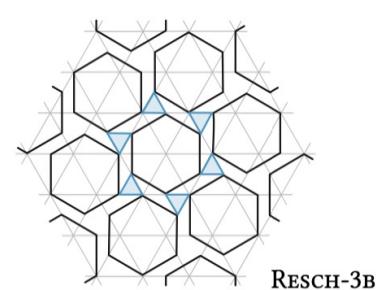
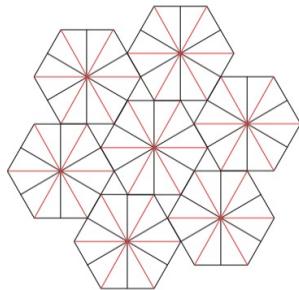
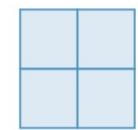
3-RoSy



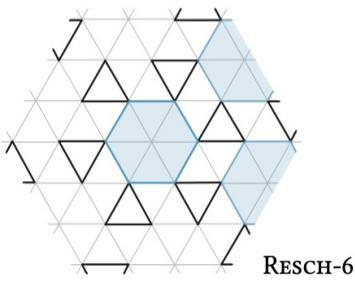
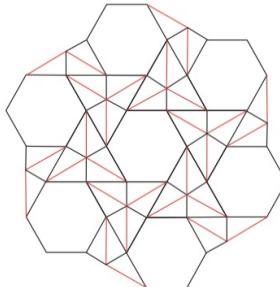
smocking pattern



4-RoSy



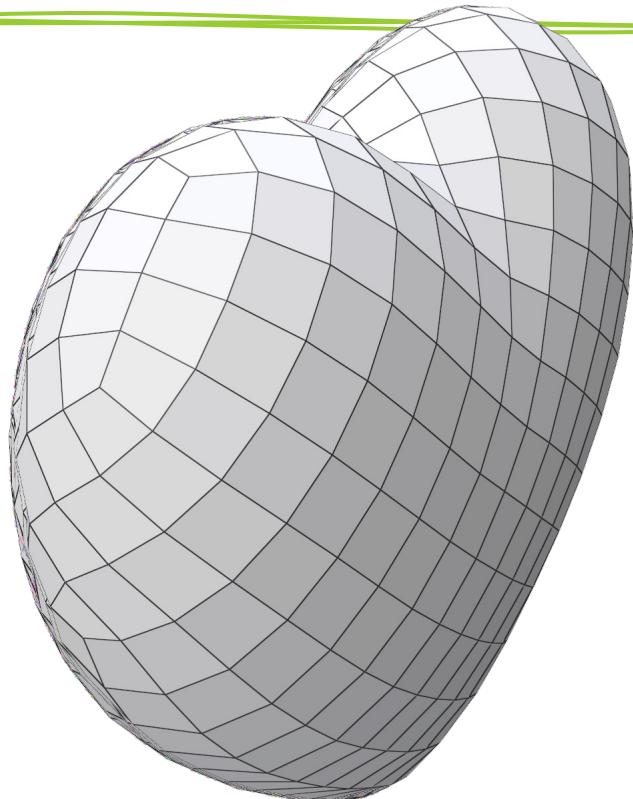
3-RoSy



6-RoSy



# Seamless Parameterization



Follow [1] to optimize for:  $Y = (y_1, y_2, \dots, y_N)$

$$\sum_f A_f \sum_{i=1}^N |y_i(f)| - 1|^2$$

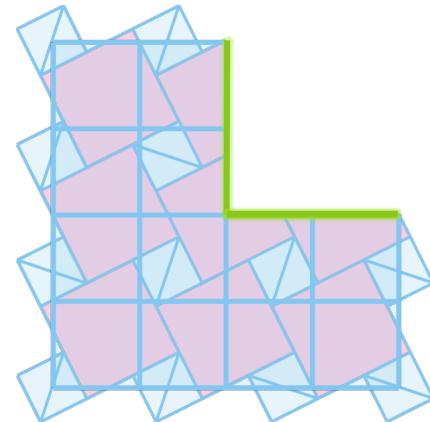
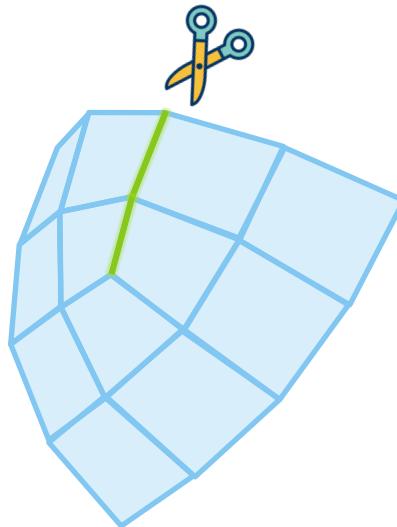
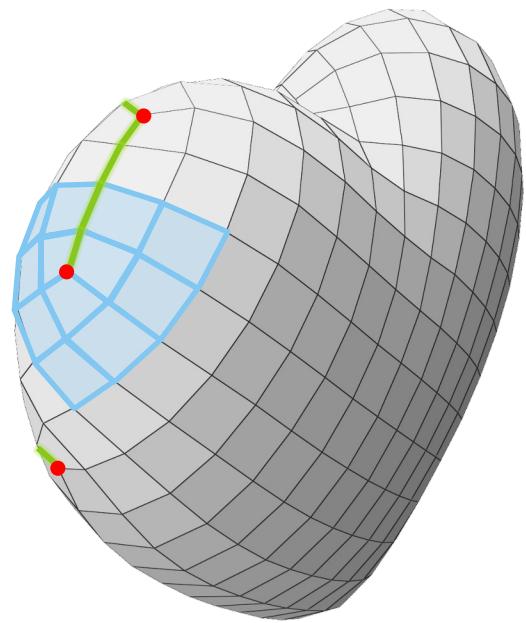
$$\sum_f A_f \sum_{i=2}^N |y_i(f) - e^{\frac{2\pi}{N}} y_{i-1}(f)|^2$$

$$s.t. \quad C_I Y = 0$$

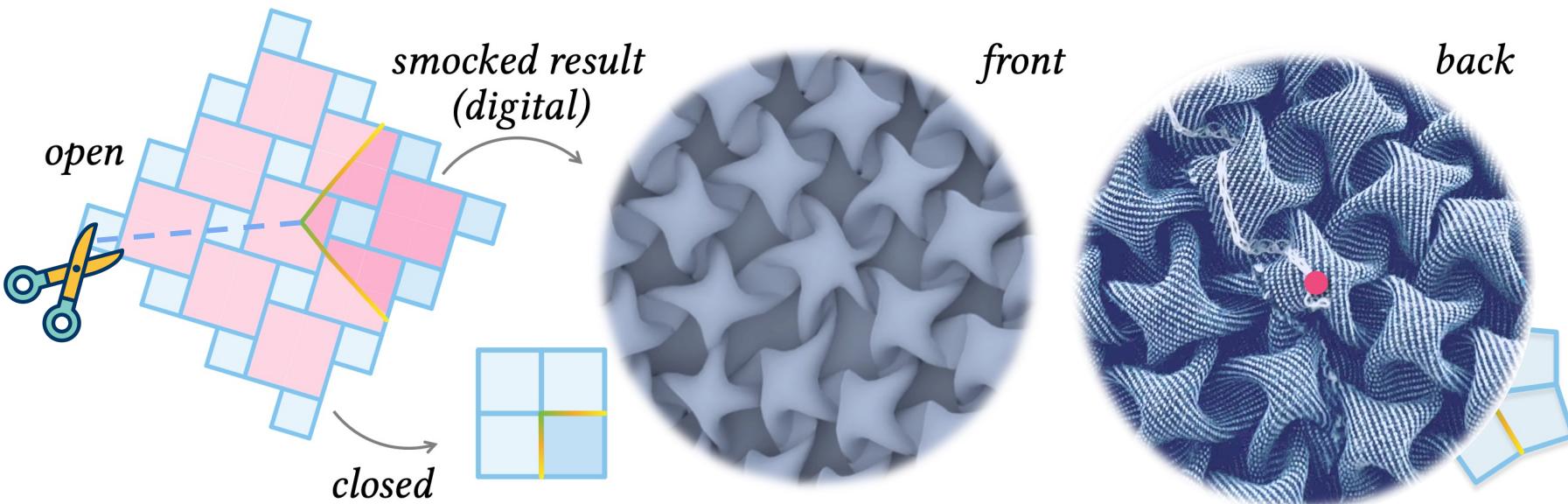
[1] “Unconventional patterns on surfaces.”,  
Meeks and Vaxman 2021

# Seamless smocking

Pull-back result



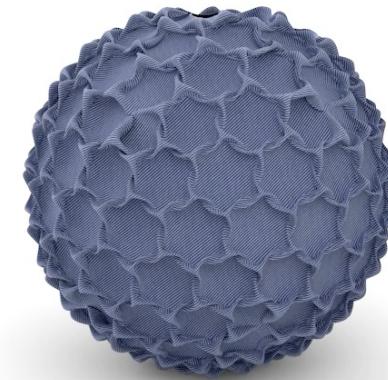
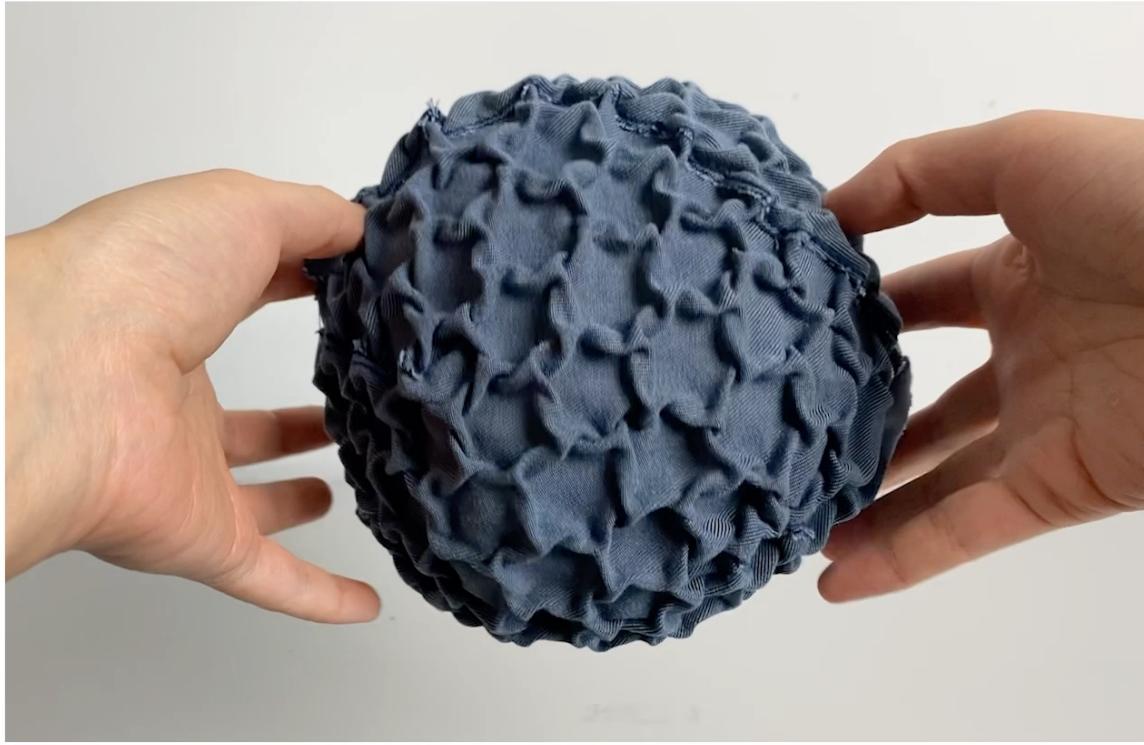
# Resch pattern for seamless smocking



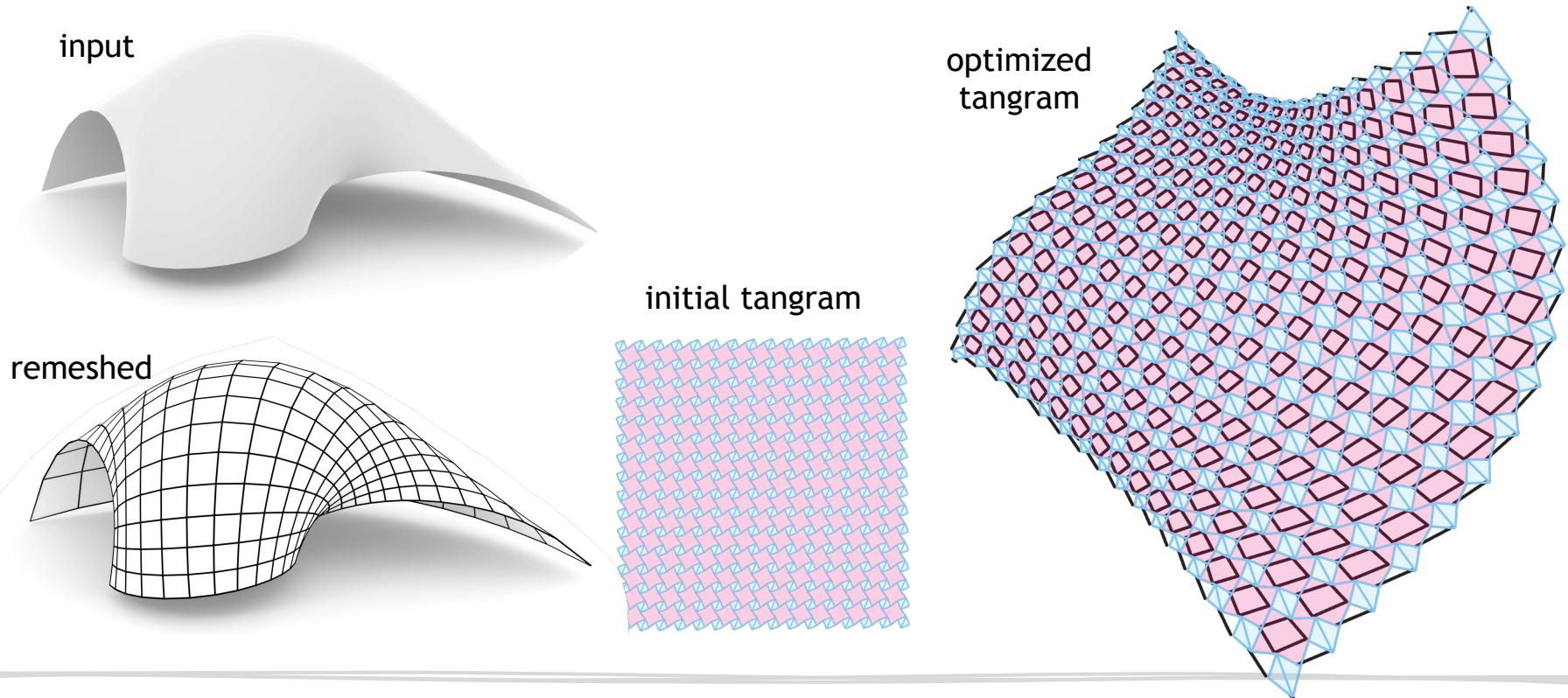
# Results: physical fabrications



# Results: physical fabrications

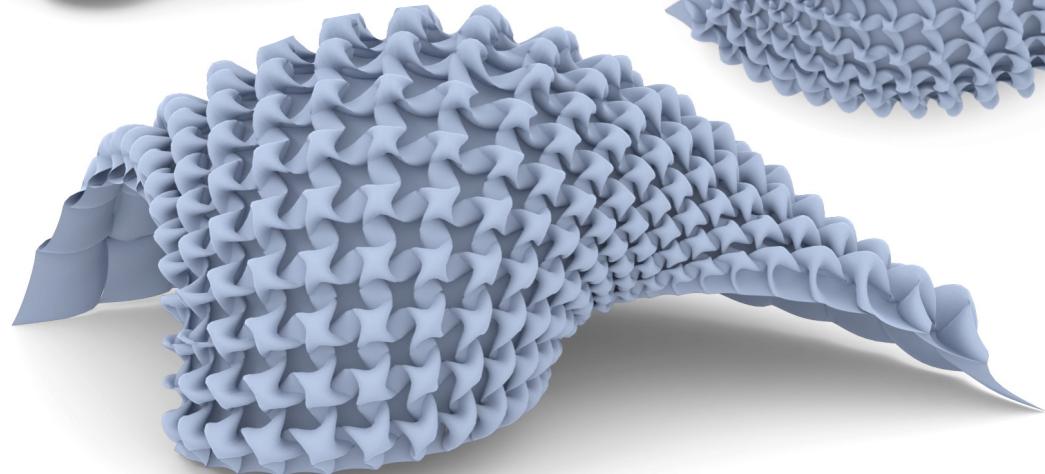


# Results : architectural design

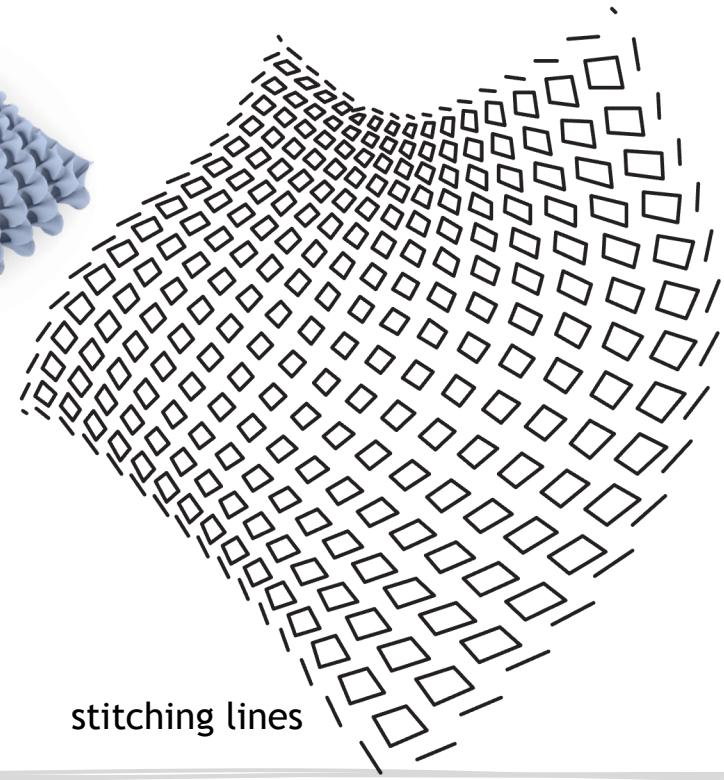


# Results: architectural design

input

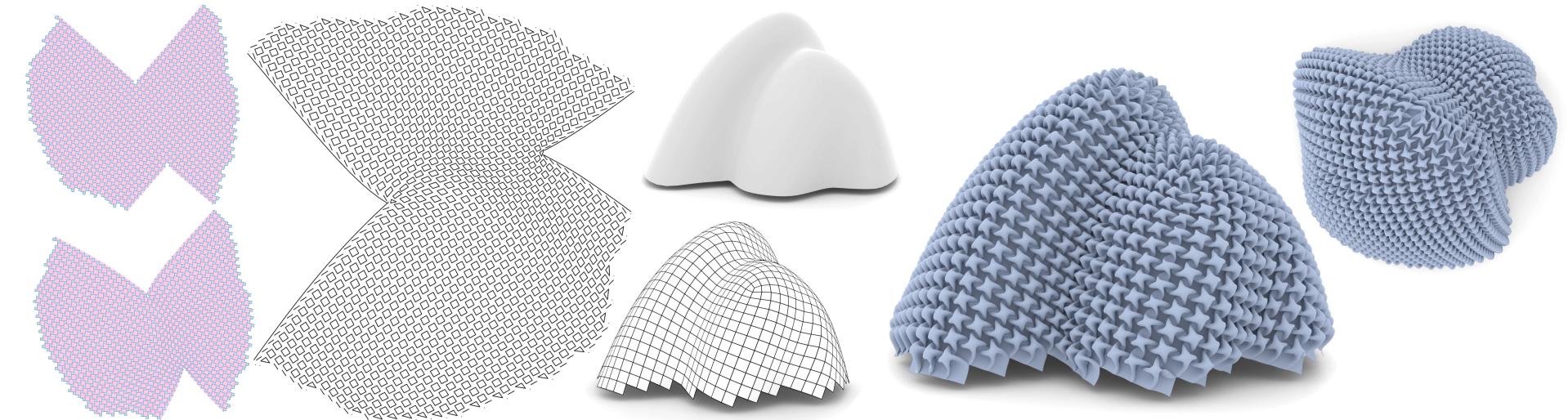


digital preview

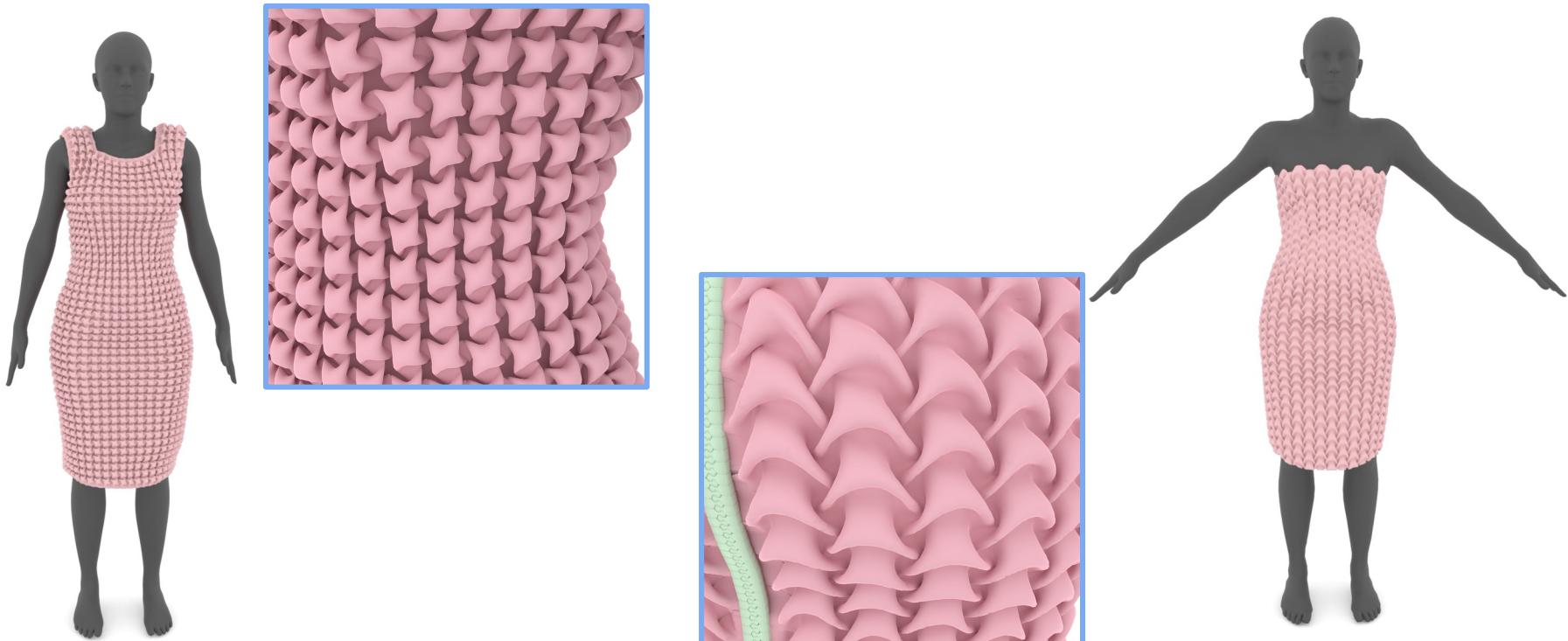


stitching lines

# Results : architectural design



# Results : garment design



# Fabric Tessellation: Realizing Free-form Surfaces by Smocking

## Thanks for your attention



The authors would like to thank the anonymous reviewers for their valuable feedback. This work was supported in part by the ERC Consolidator Grant No. 101003104 (MYCLOTH). Special thanks to Ningfeng Zhou for her assistance in fabricating the heart and cloud shapes, and to all members of IGL for the insightful discussions and kind support.

