

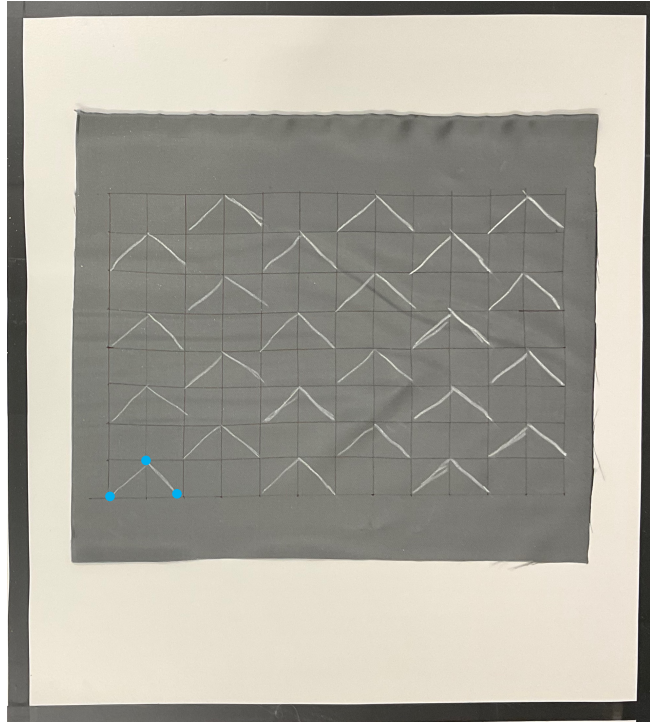
# Fabric Tessellation: Realizing Freeform Surfaces by Smocking

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

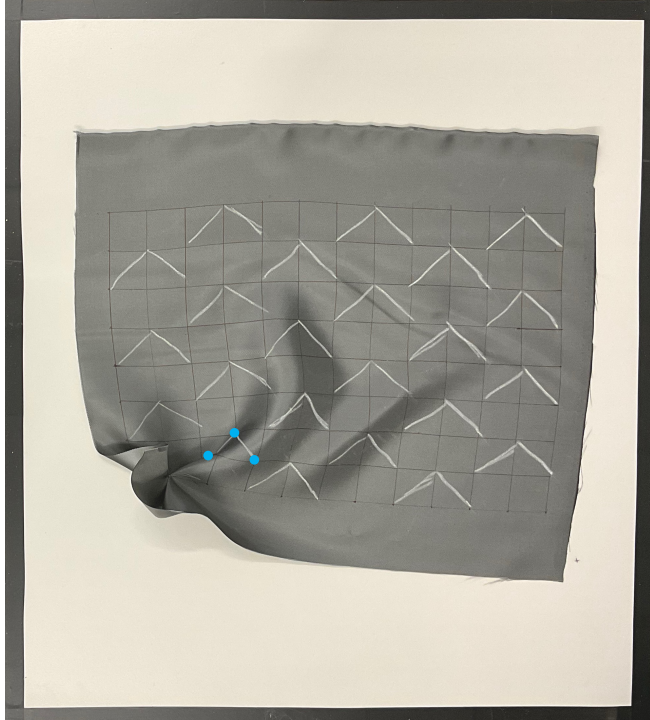


# What is smocking?

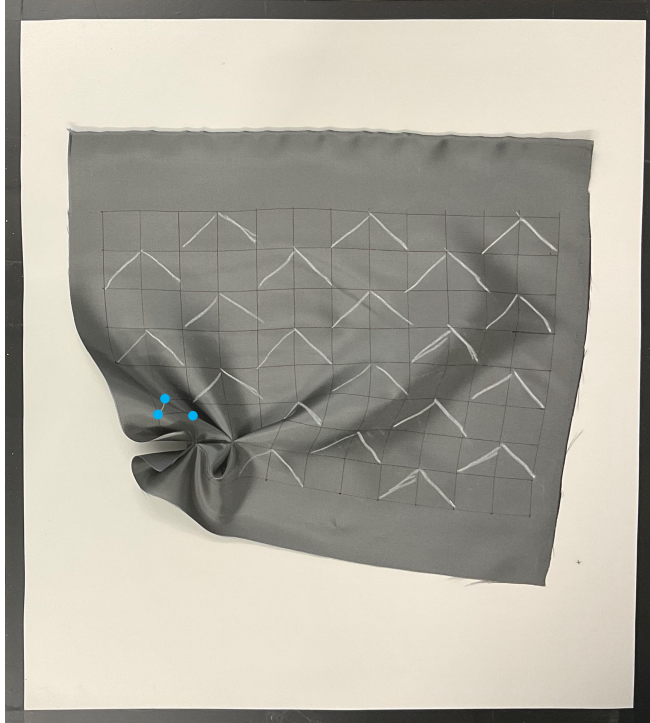




# What is smocking?



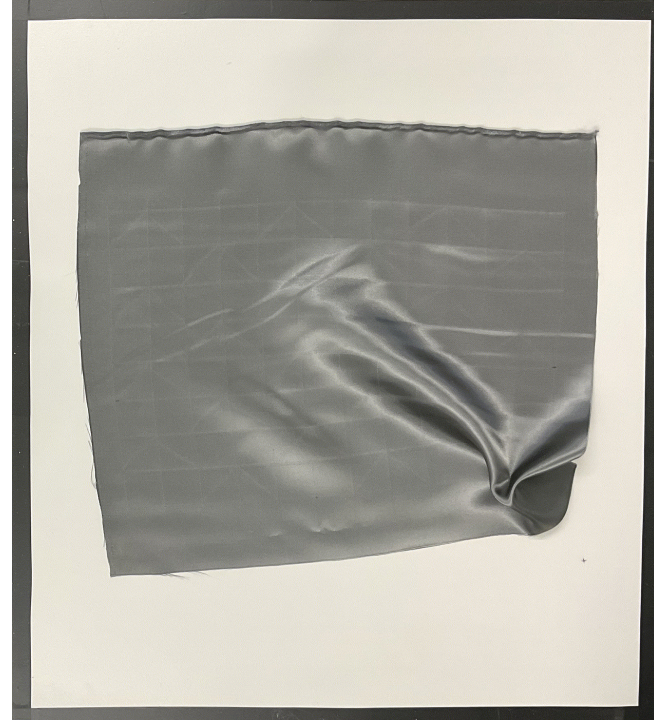
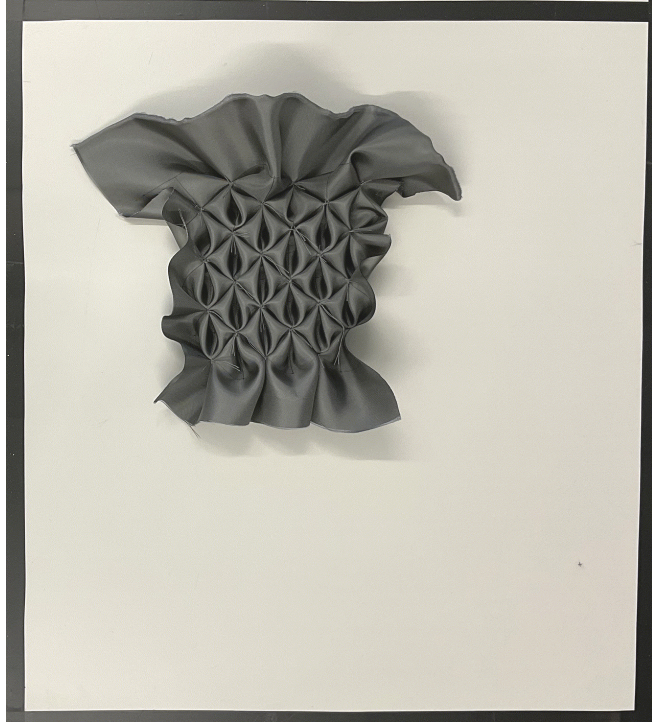
# What is smocking?



# What is smocking?



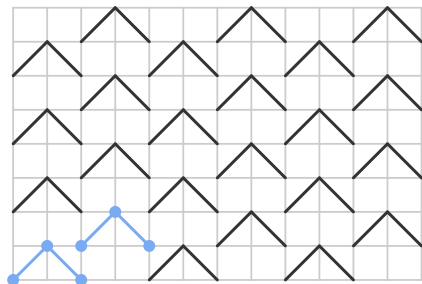
# What is smocking?



# Forward problem

input

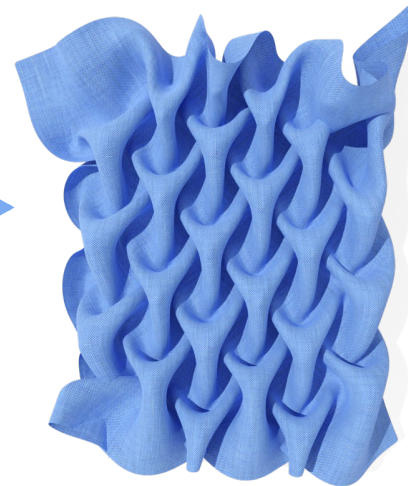
2D smocking pattern



?

output

3D smocked result

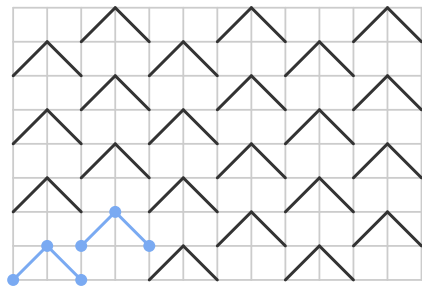




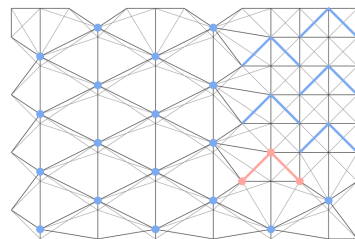
# Forward problem

input

2D smocking pattern



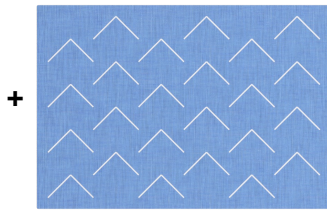
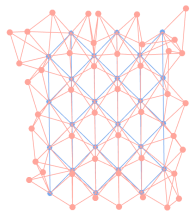
forward problem solved by [1]



1. merge multiple points into a single one

2. the embedding is solved in 2D

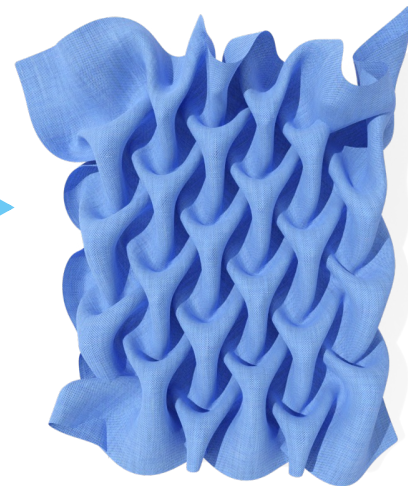
$$\min_{X \in \mathbb{R}^2} \mathcal{E}(X)$$



3. ARAP deformation

output

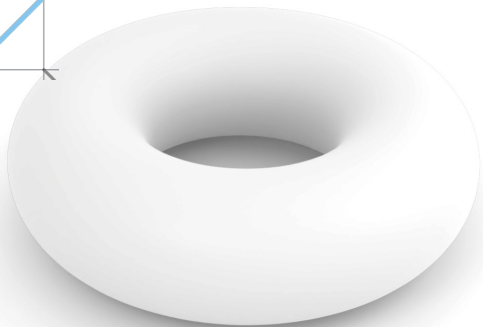
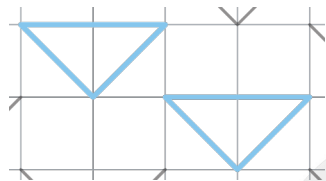
3D smocked result



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

# Inverse design for smocking

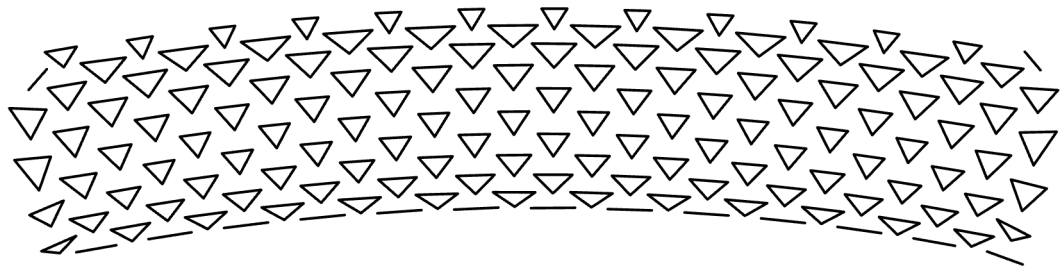
input 3D shape + smocking type



## requirements

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

output modified smocking pattern

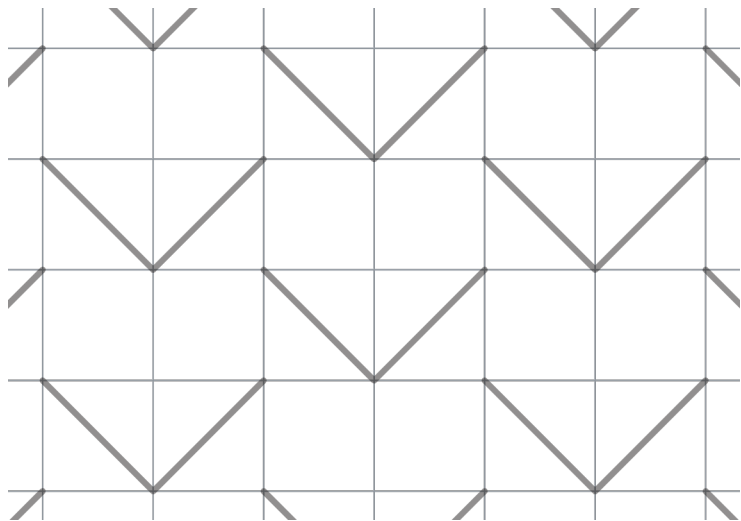


after  
fabrication

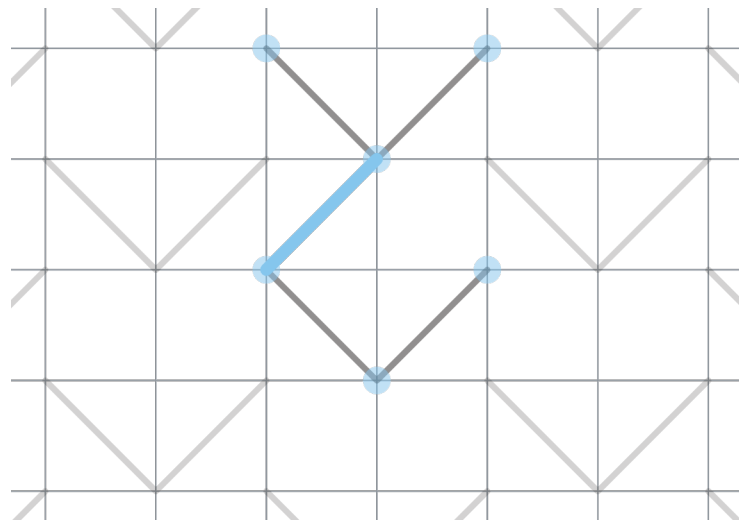


# Methodology : extract tangram

smocking pattern



underlay edge

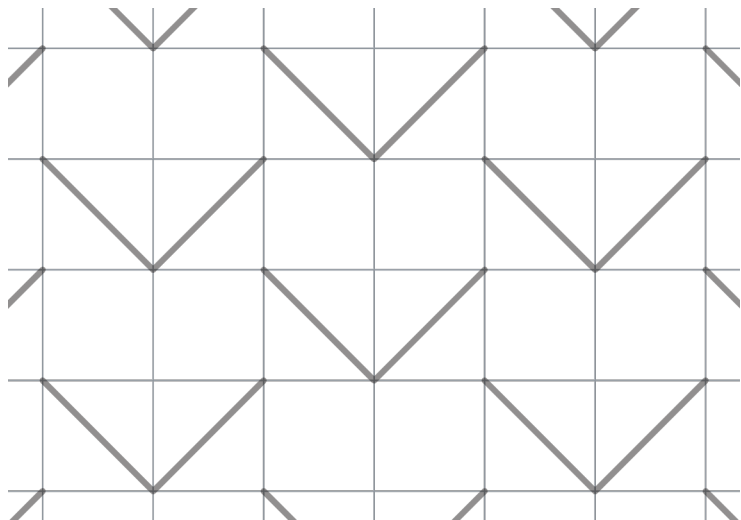


connecting two different stitching lines



# Methodology : extract tangram

smocking pattern



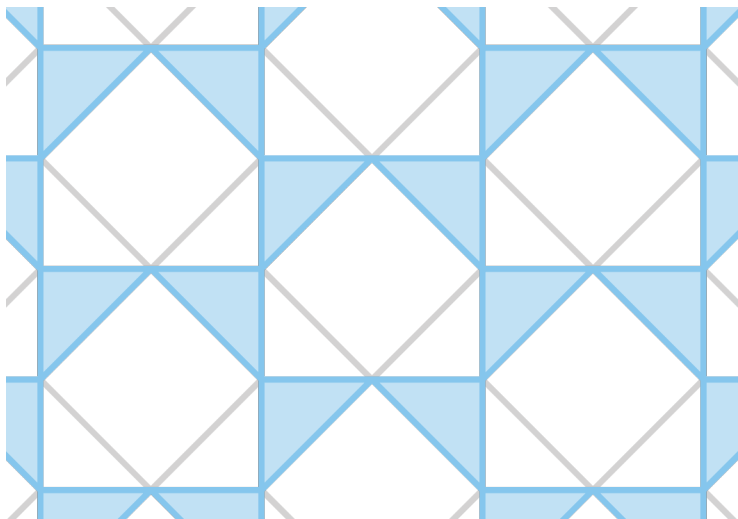
tangram



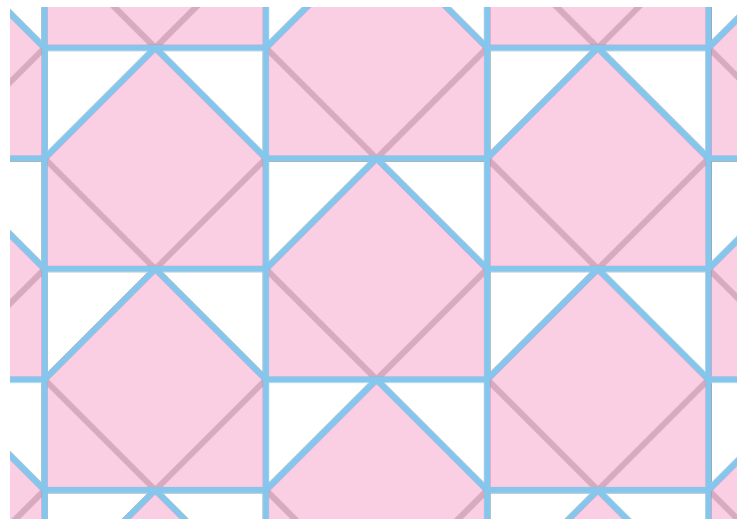
subgraph consisting of all  
underlay edges

# Methodology : extract tangram

underlay faces

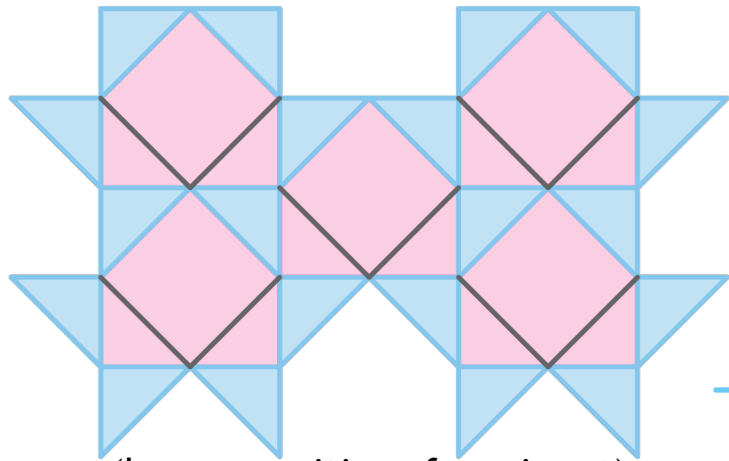


pleat faces

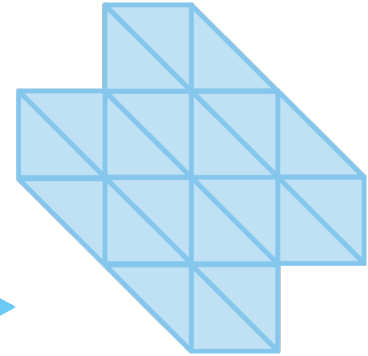
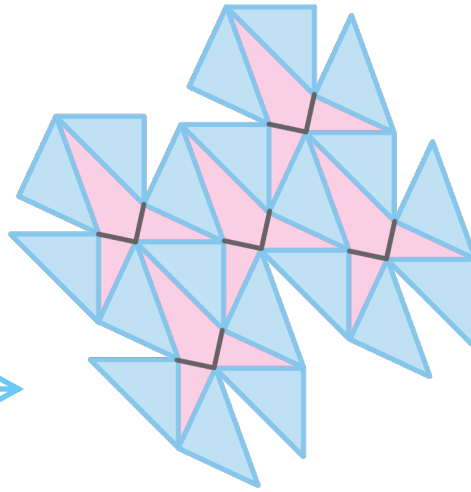


bounded regions that contain  
stitching lines

# Methodology : closing tangram



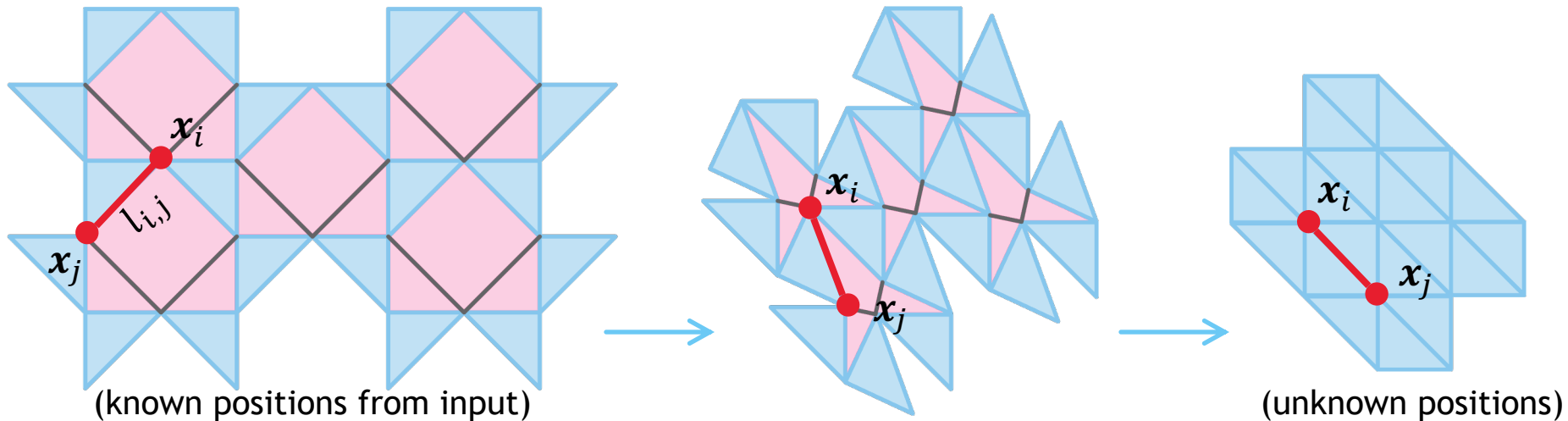
(known positions from input)



(unknown positions)

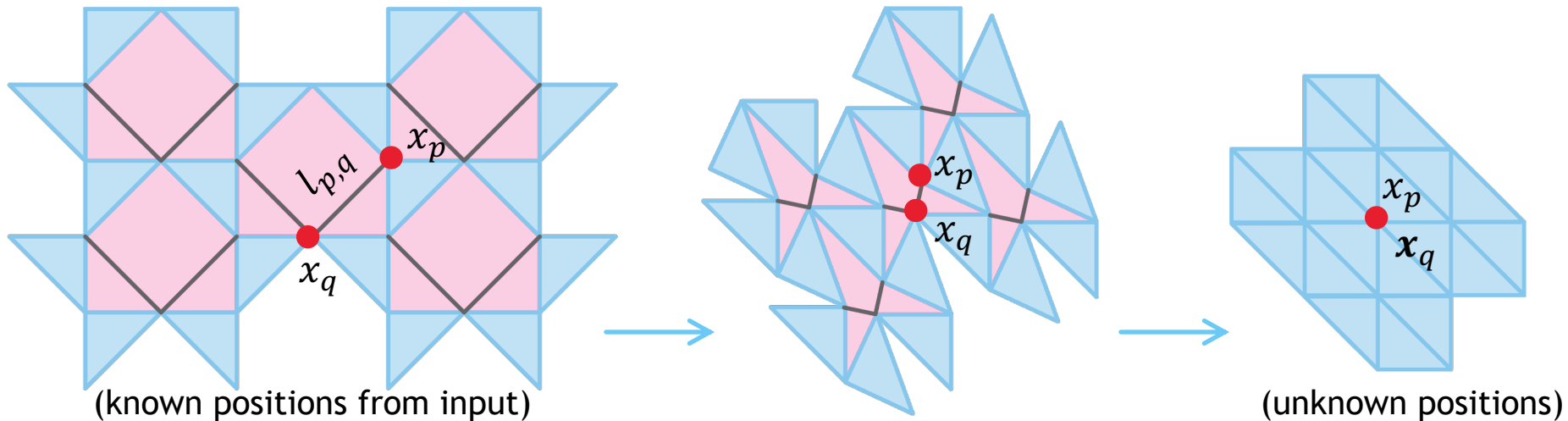


# Methodology : closing tangram



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

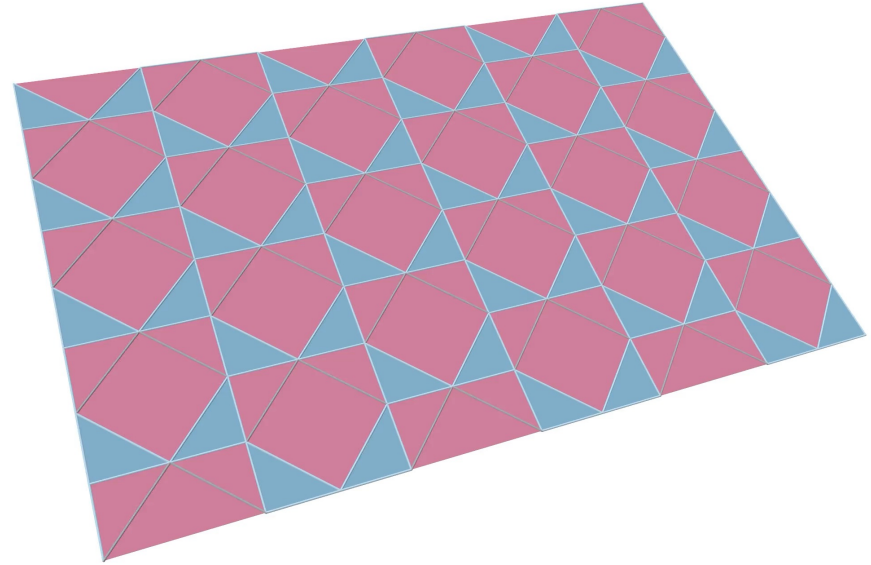
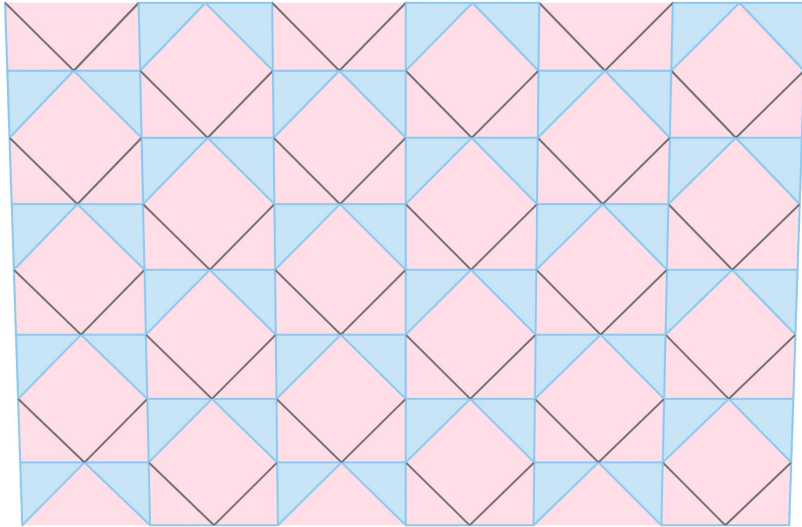
# Methodology : closing tangram



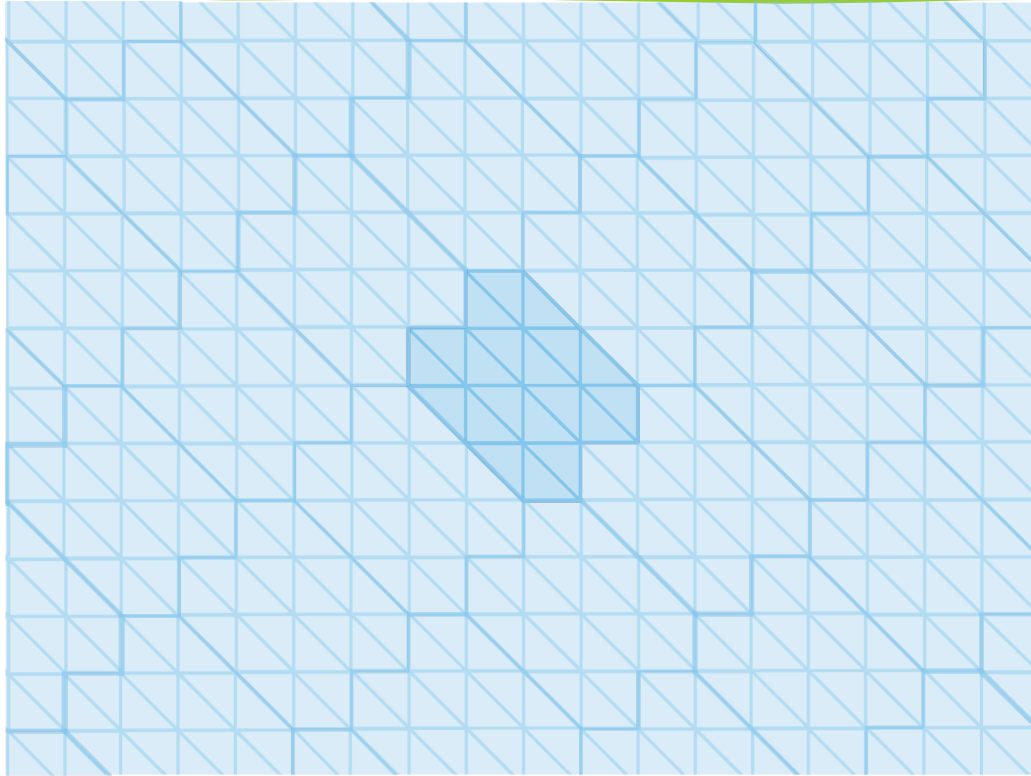
$$E_{\text{rigid}} = \sum_{(i,j) \in \mathcal{E}_r} (\|x_i - x_j\| - l_{i,j})^2$$

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

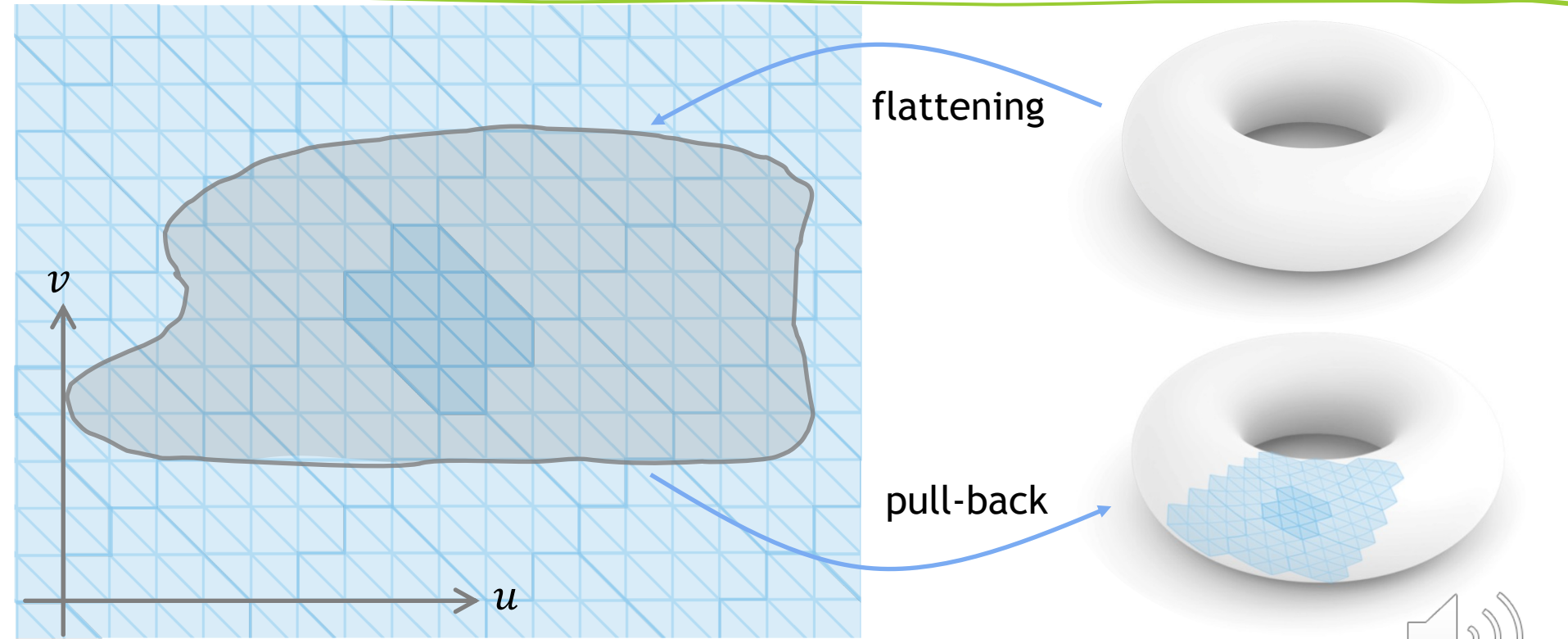
# Methodology : closing tangram



# Methodology: plane tiling

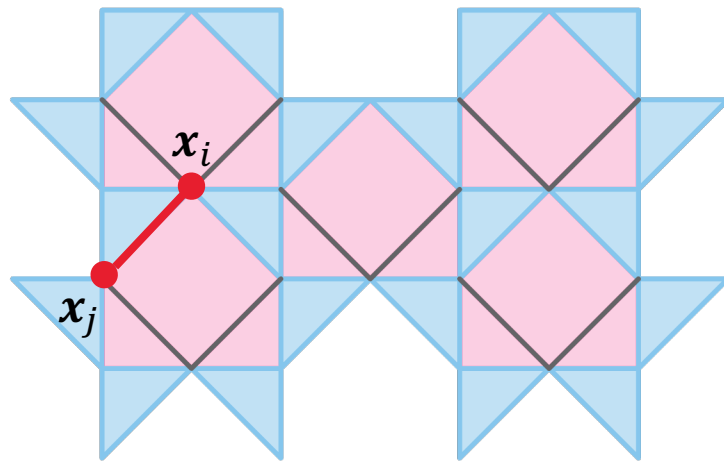
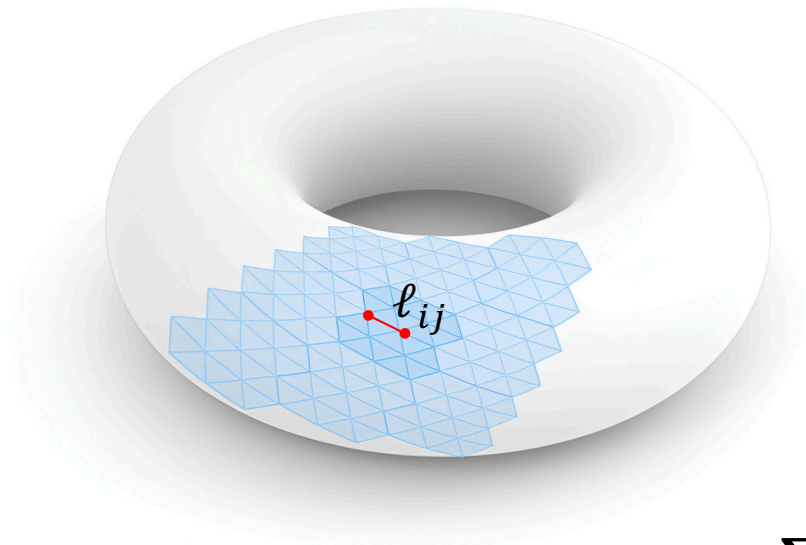


# Methodology: pull-back



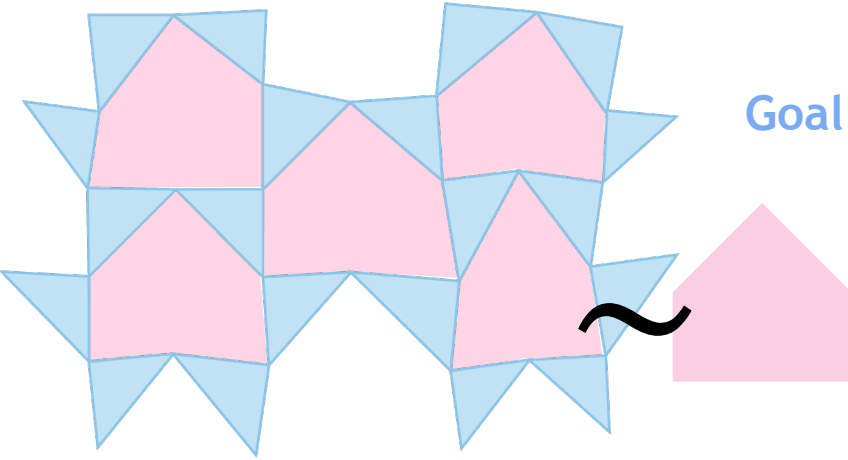


# Methodology: optimize Tangram



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

# Methodology : pleat regularity



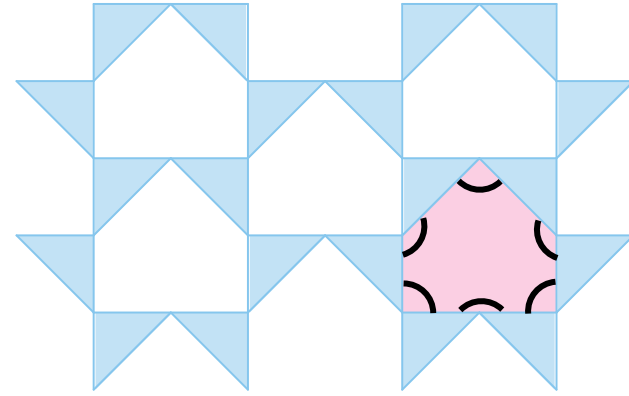
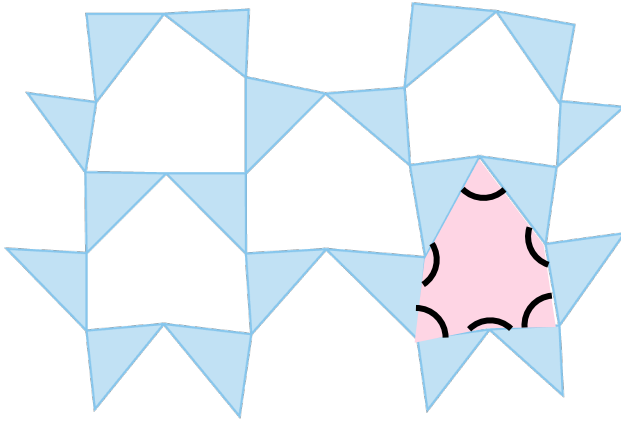
Goal the pleats are regular



Output: modified pattern

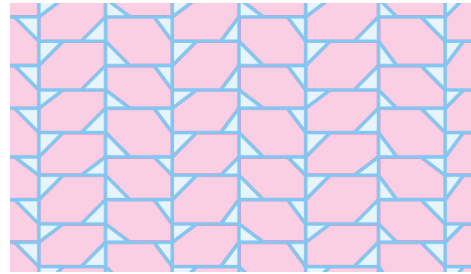


# Methodology : pleat regularity



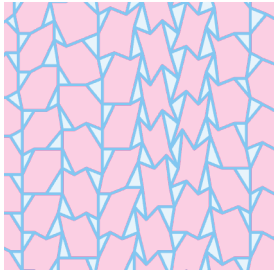
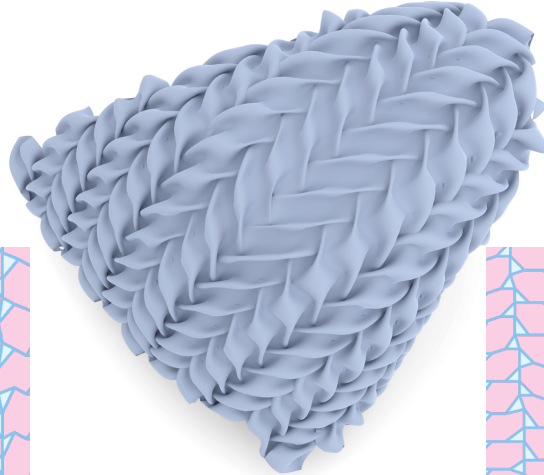
$$E_{\text{pleat}}(X) = \sum_{(i,j),(j,k) \in F_p} \left( \frac{\angle(x_i, x_j, x_k) - \angle(\hat{x}_i, \hat{x}_j, \hat{x}_k)}{2\pi} \right)^2$$

# Methodology : pleat regularity

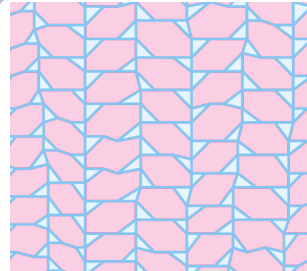


initial tangram

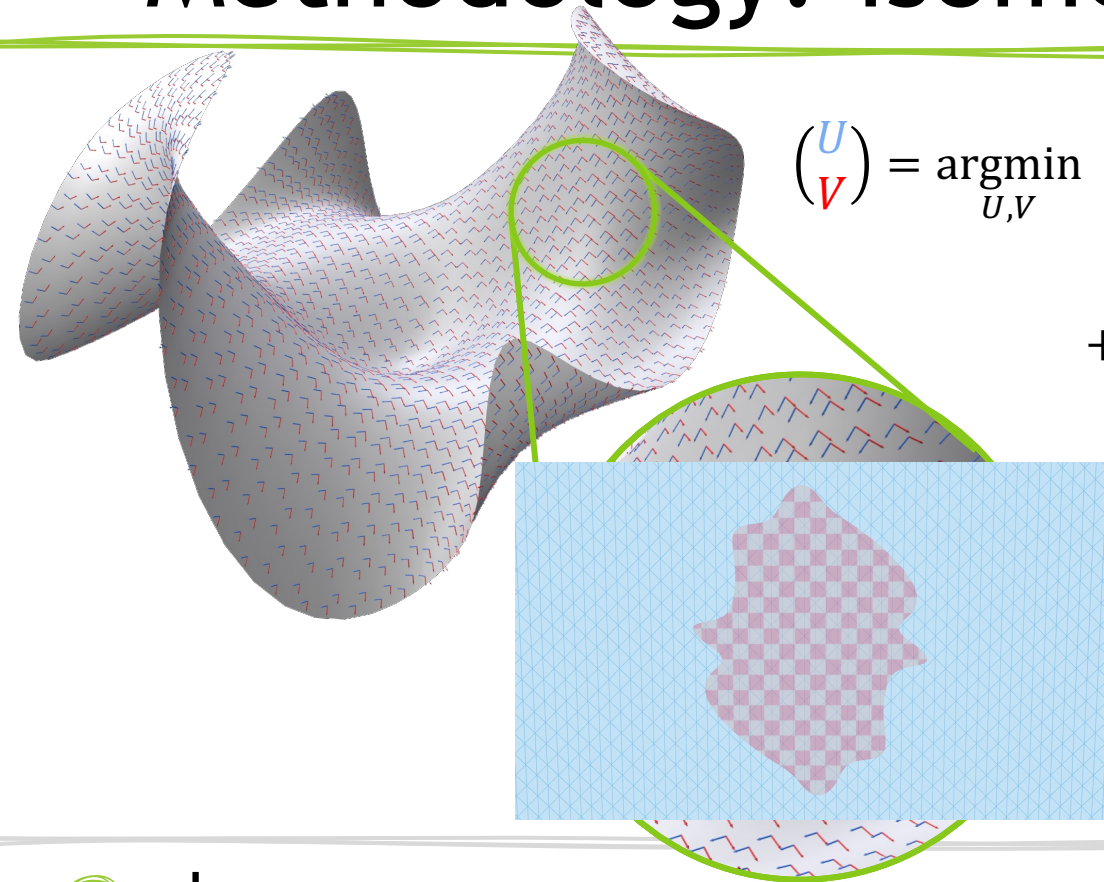
optimized tangram/result  
*without* pleat regularity



optimized tangram/result  
*with* pleat regularity



# Methodology: isometric flattening

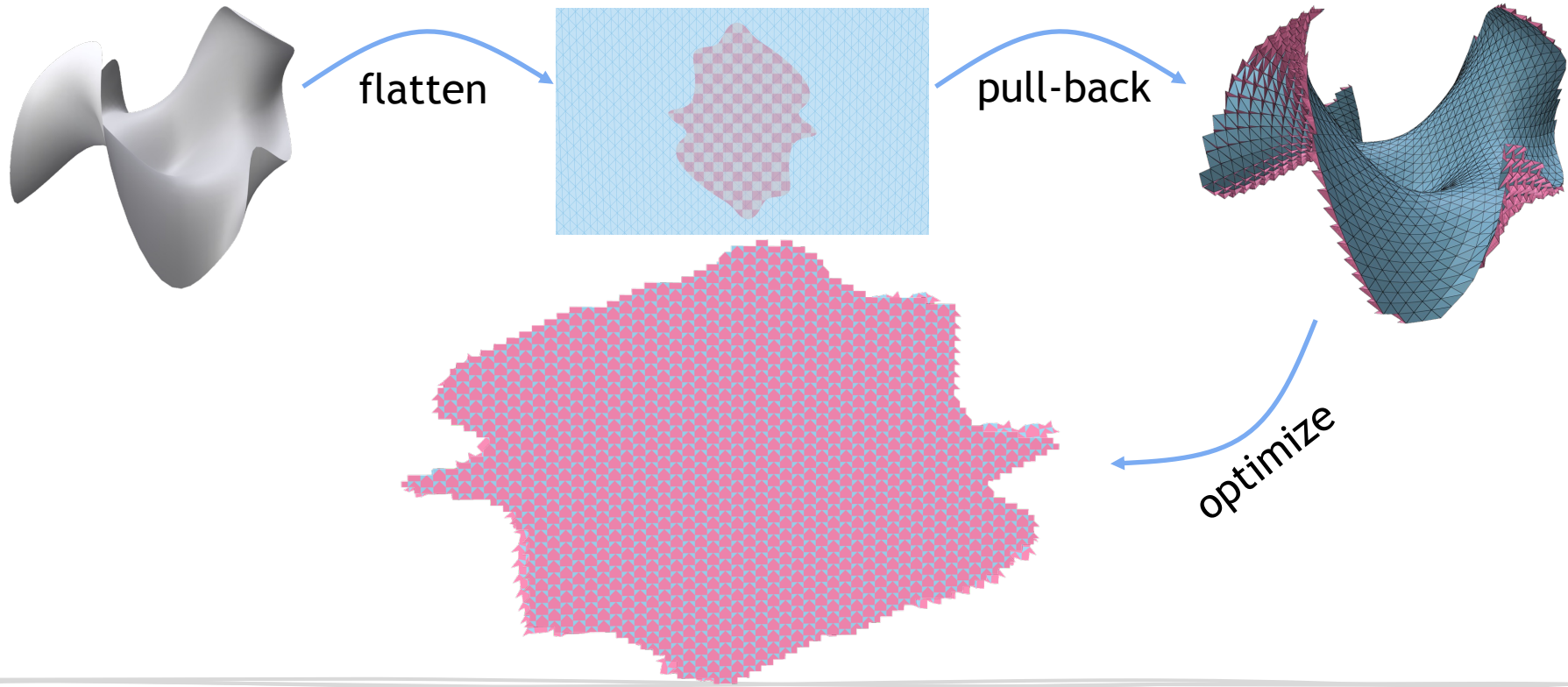


$$\begin{pmatrix} U \\ V \end{pmatrix} = \operatorname{argmin}_{U,V} \alpha \sum_f A_f ( (|U(f)| - 1)^2 + (|V(f)| - 1)^2 )$$

$$+ \beta \sum_f A_f (V(f) - iU(f))^2$$

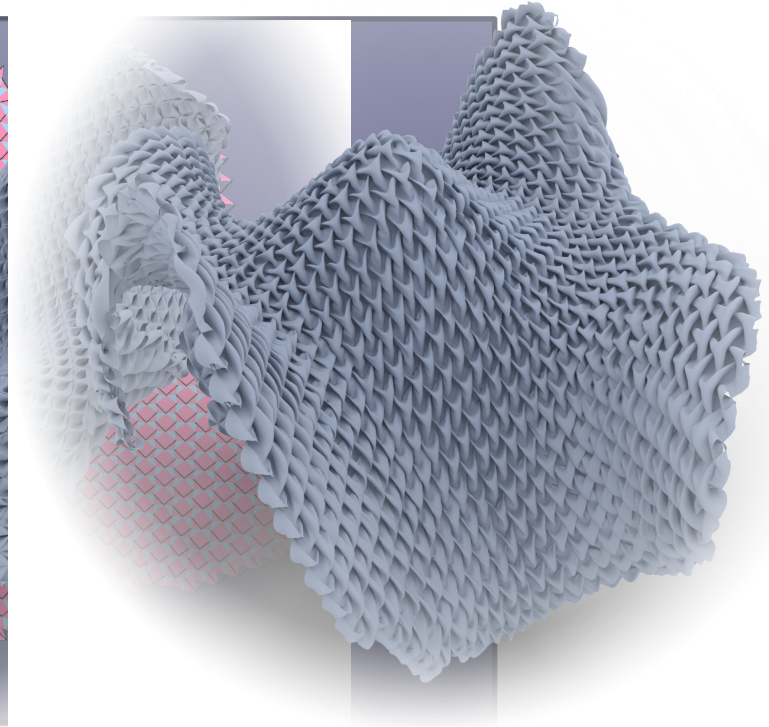
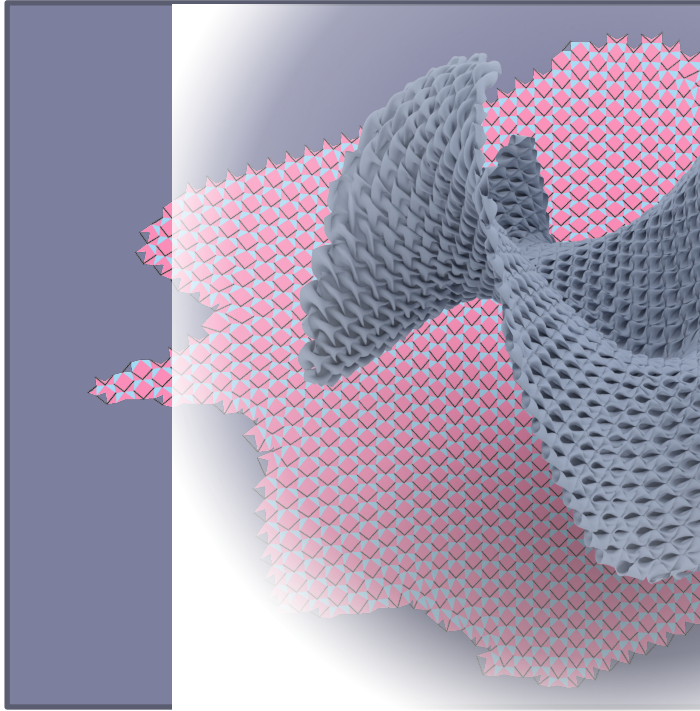
$$\text{s.t. } C \begin{pmatrix} U \\ V \end{pmatrix} = 0 \quad (\text{integrability})$$

# Methodology: recap



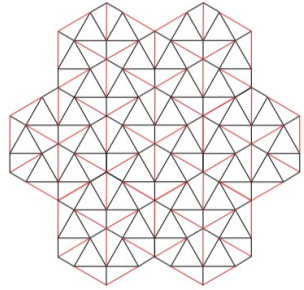


# Methodology: extract stitching

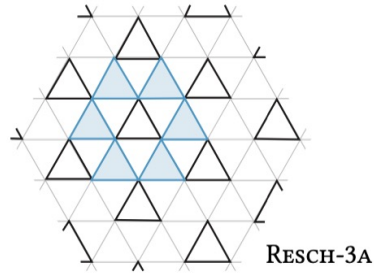


# Resch pattern for seamless smocking

crease pattern

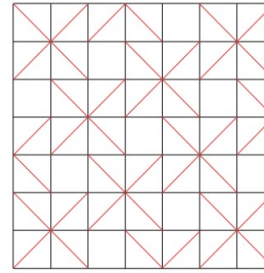


smocking pattern

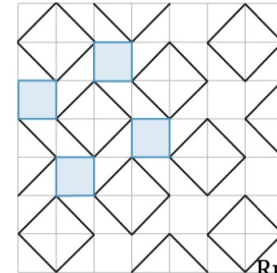


RESCH-3A

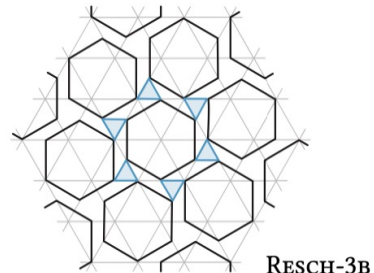
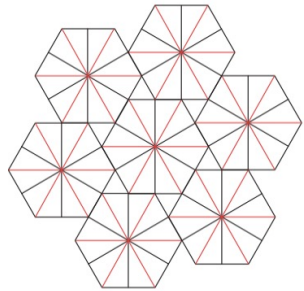
crease pattern



smocking pattern

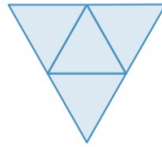


RESCH-4

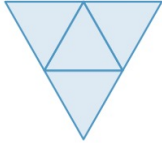


RESCH-3B

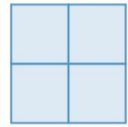
3-RoS<sub>y</sub>



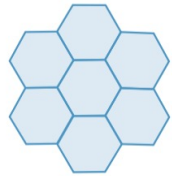
3-RoS<sub>y</sub>



4-RoS<sub>y</sub>

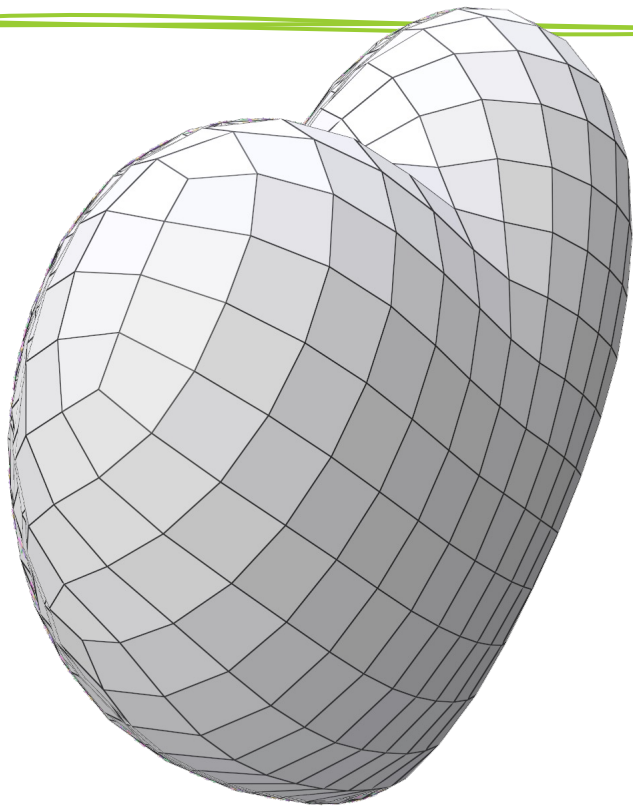


6-RoS<sub>y</sub>





# Seamless Parameterization



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

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

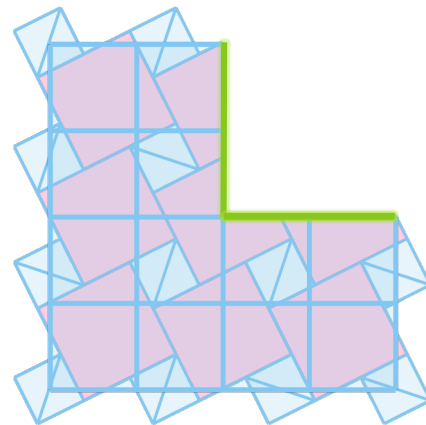
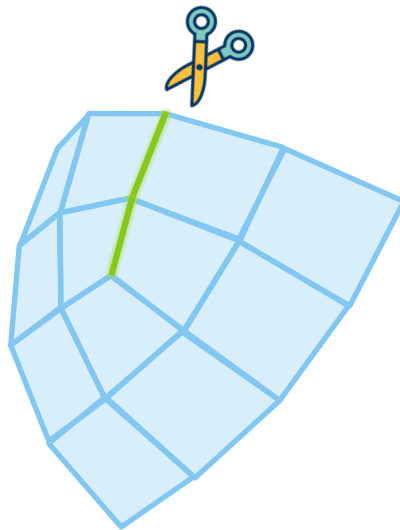
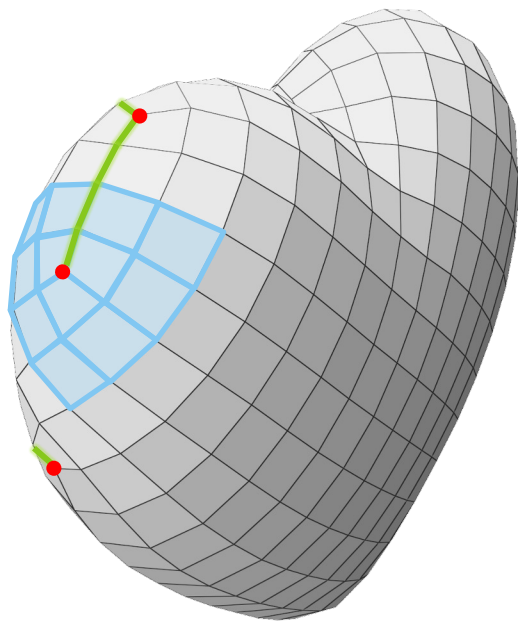
$$\sum_f A_f \sum_{i=2}^N \left| y_i(f) - e^{\frac{2\pi}{N}} y_{i-1}(f) \right|^2$$

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

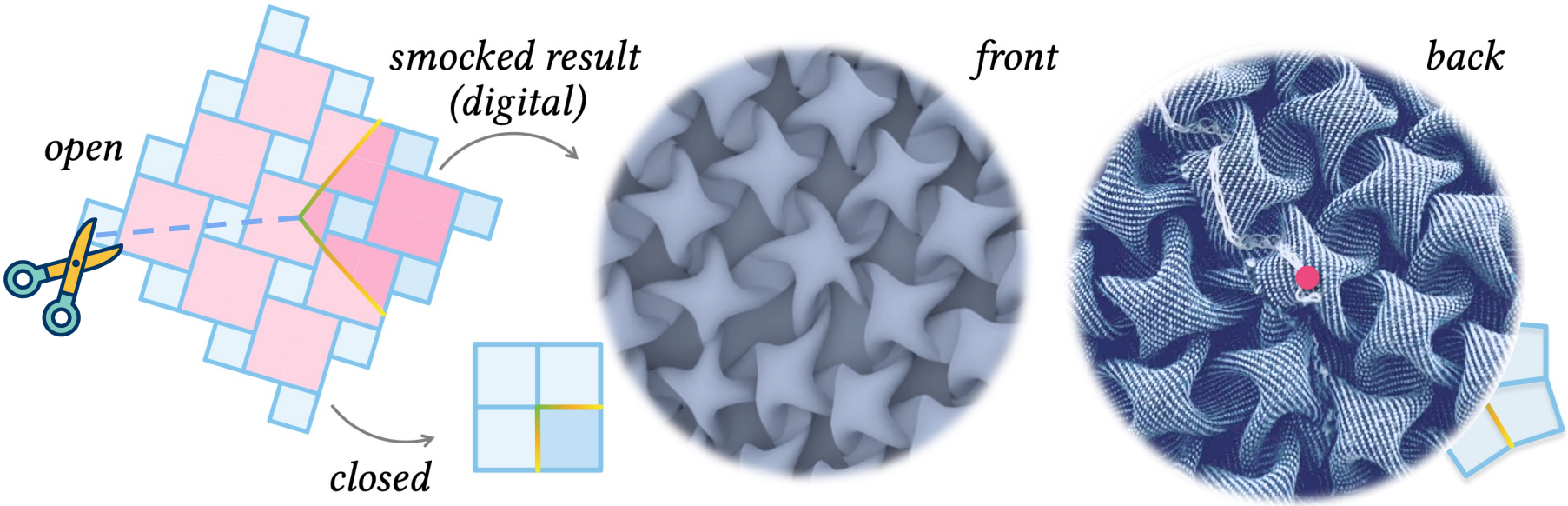
[1] “Unconventional patterns on surfaces.”,  
Meeks and Vaxman 2021

# Seamless smocking

Pull-back result



# Resch pattern for seamless smocking



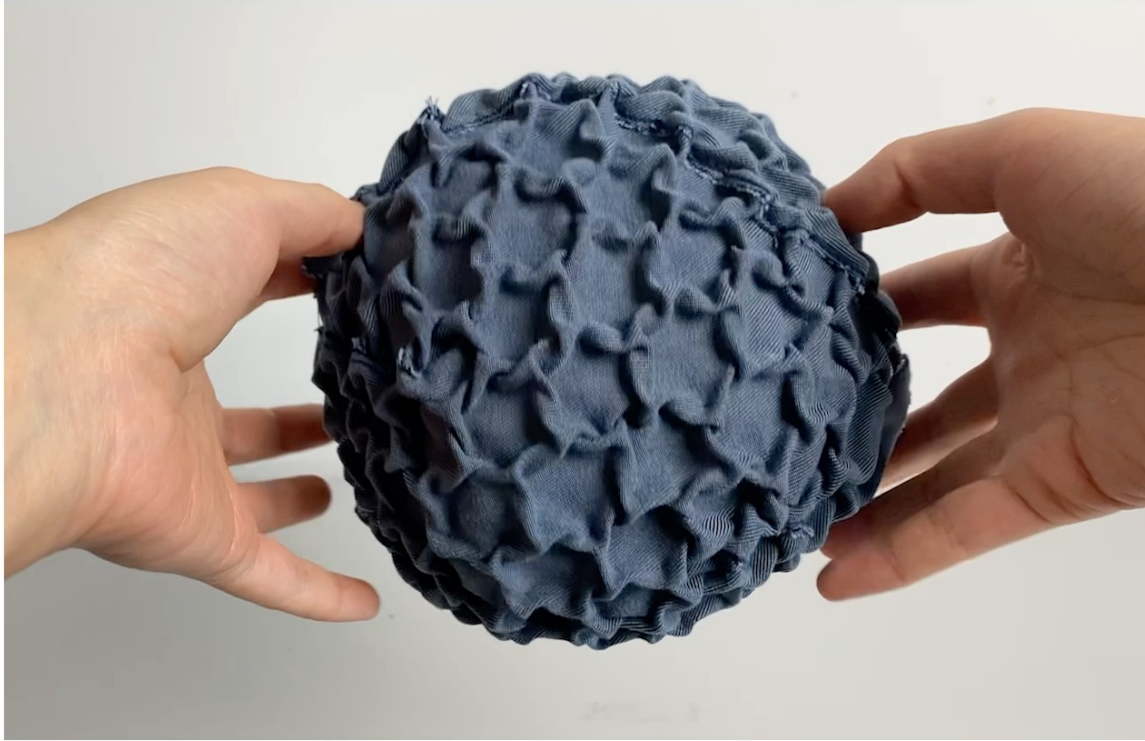
# Results: physical fabrications

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# Results: physical fabrications

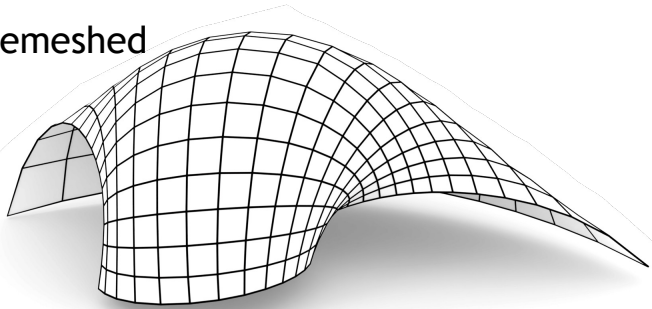


# Results : architectural design

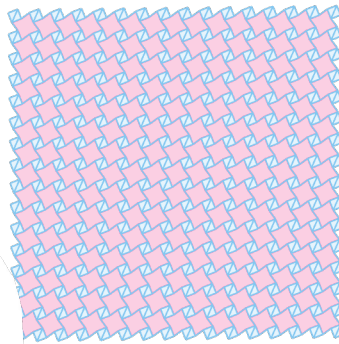
input



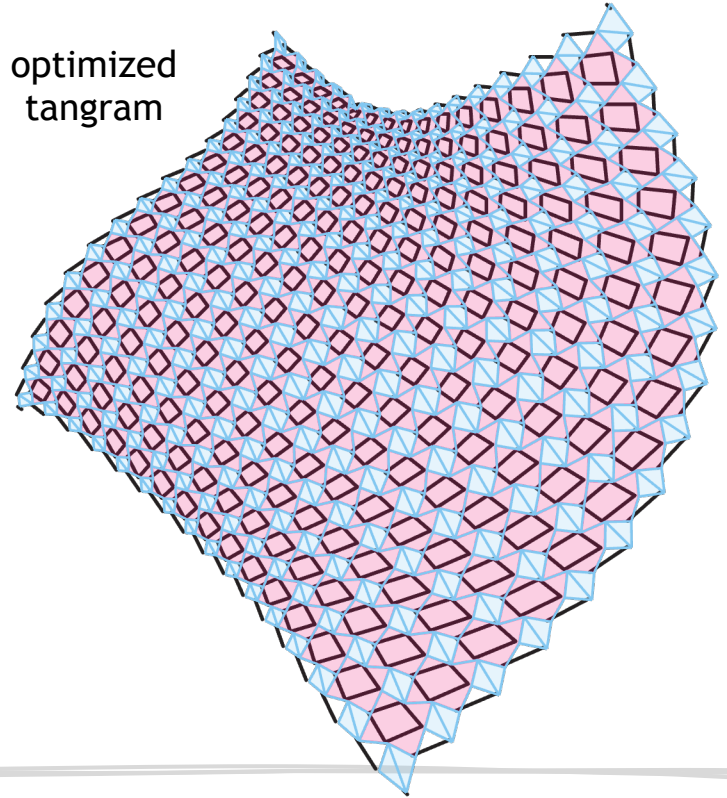
remeshed



initial tangram

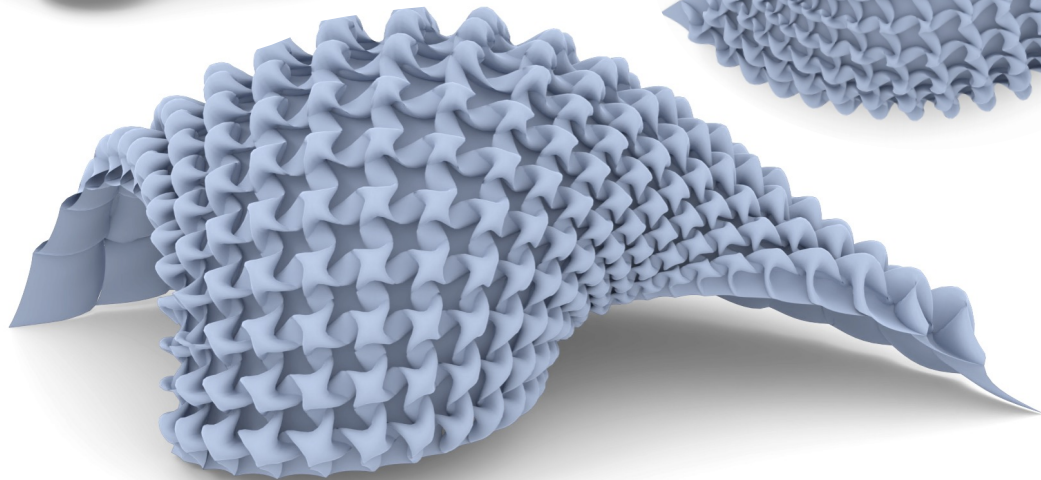
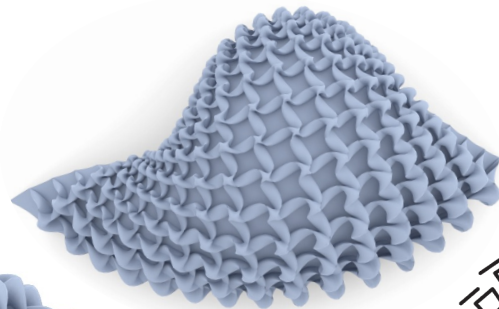


optimized  
tangram

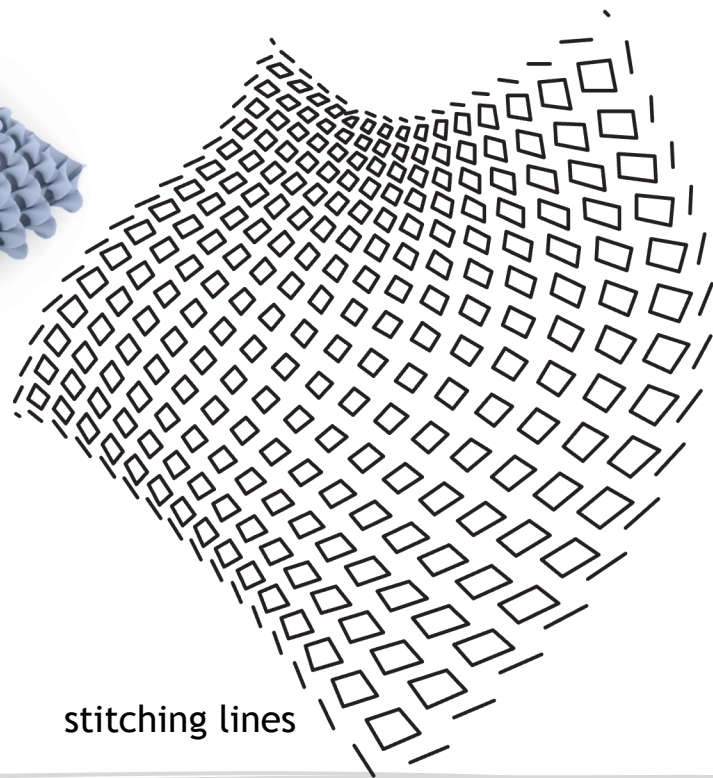


# Results: architectural design

input



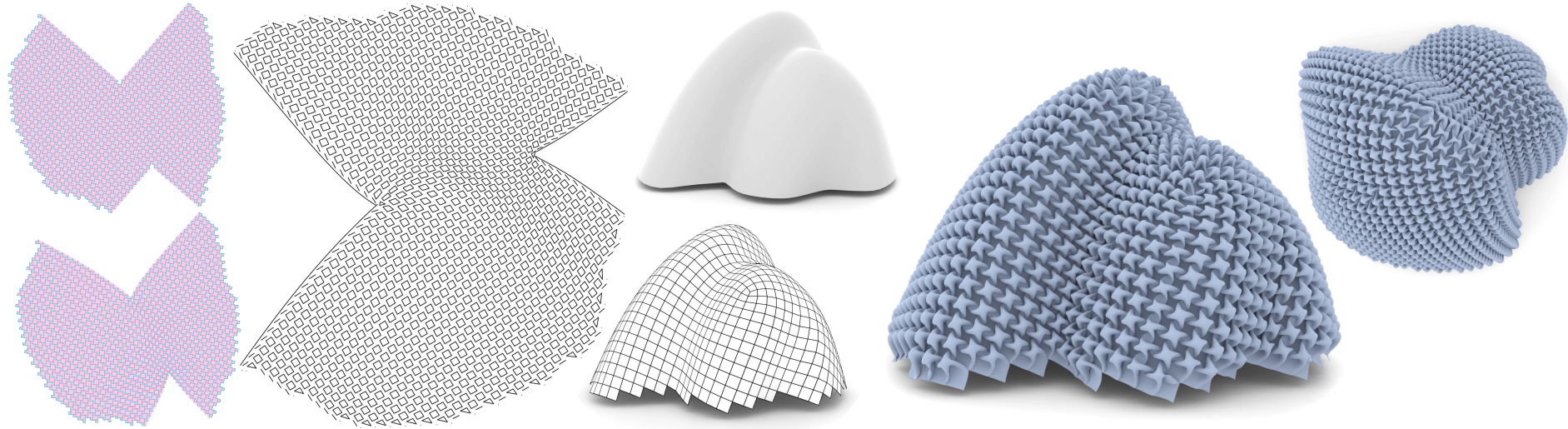
digital preview



stitching lines

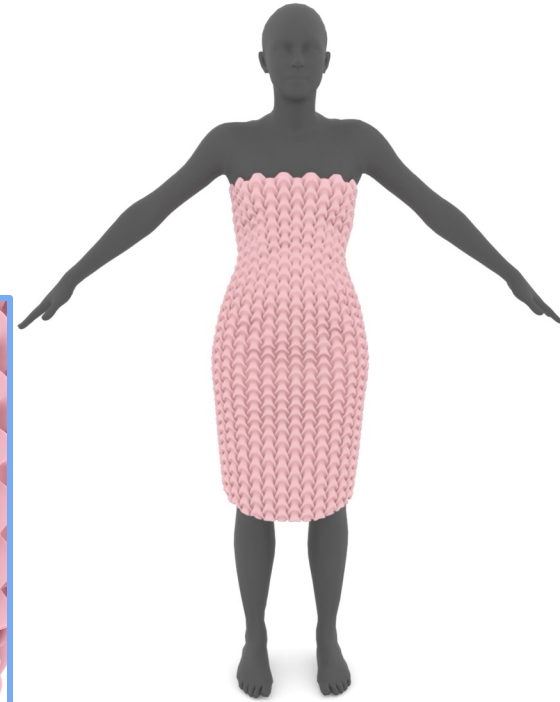
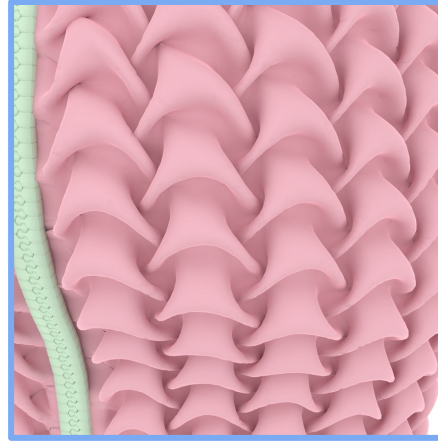
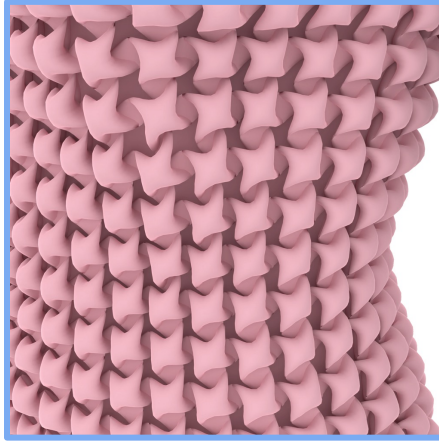


# Results : architectural design





# Results : garment design



## 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.

