Bead Patterns in Free-Form Shape Optimization

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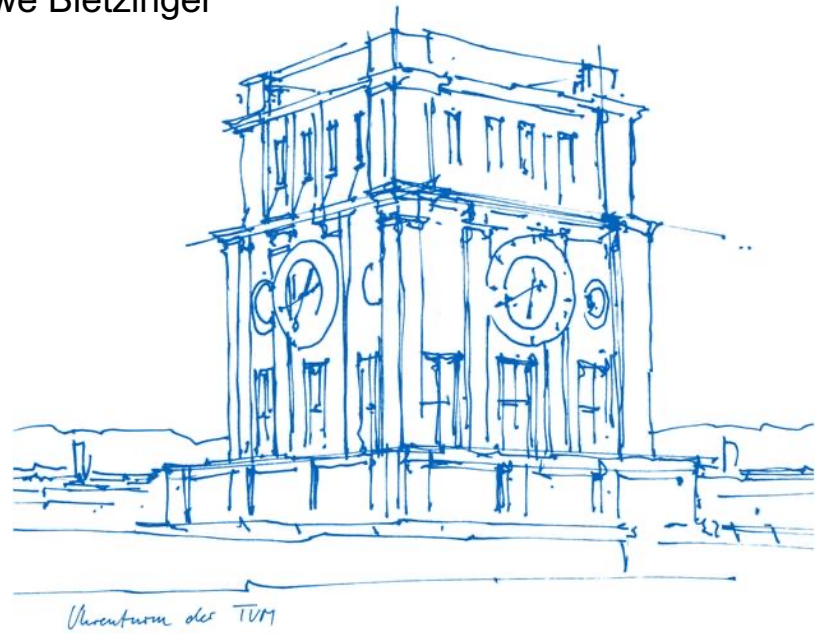

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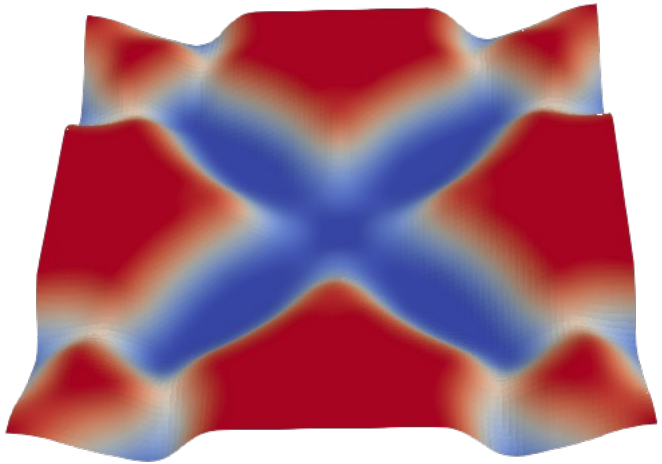
Outline

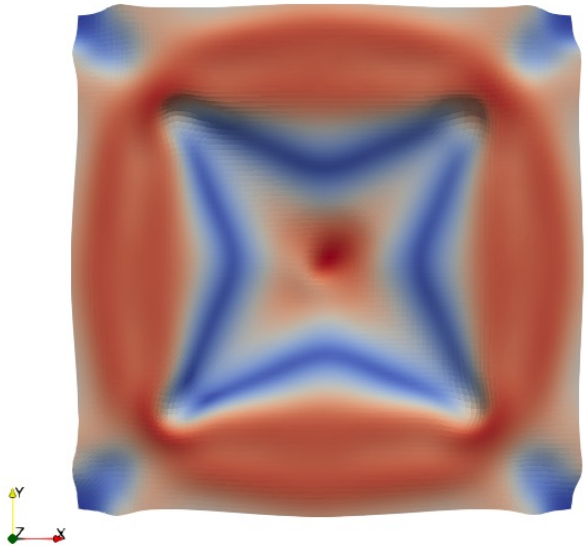
1. Introduction
2. Vertex Morphing
3. Bead Parameterization
4. Enhancement to variable bead heights
5. Conclusion / Outlook



Introduction

Free-form node-based parameterization techniques:

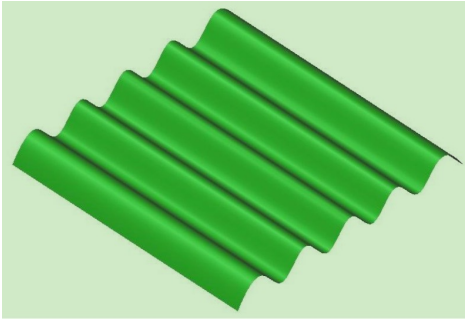
- Large freedom of optimal design
- Identification of patterns and interpretation of final shapes not straight forward



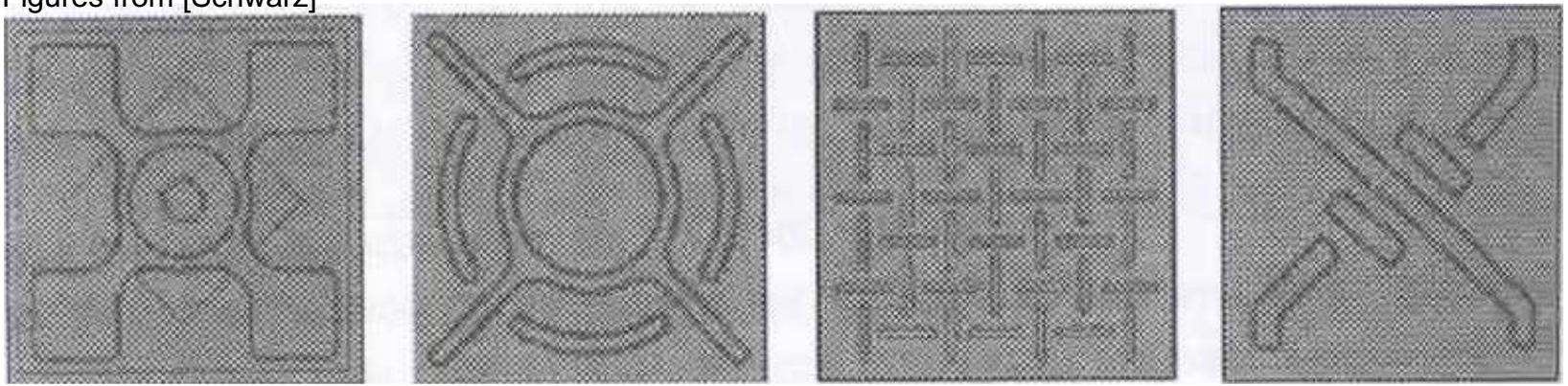
Introduction

- Bead shapes are preferred
- Patterns can be identified, interpreted

Figure from [Daoud]



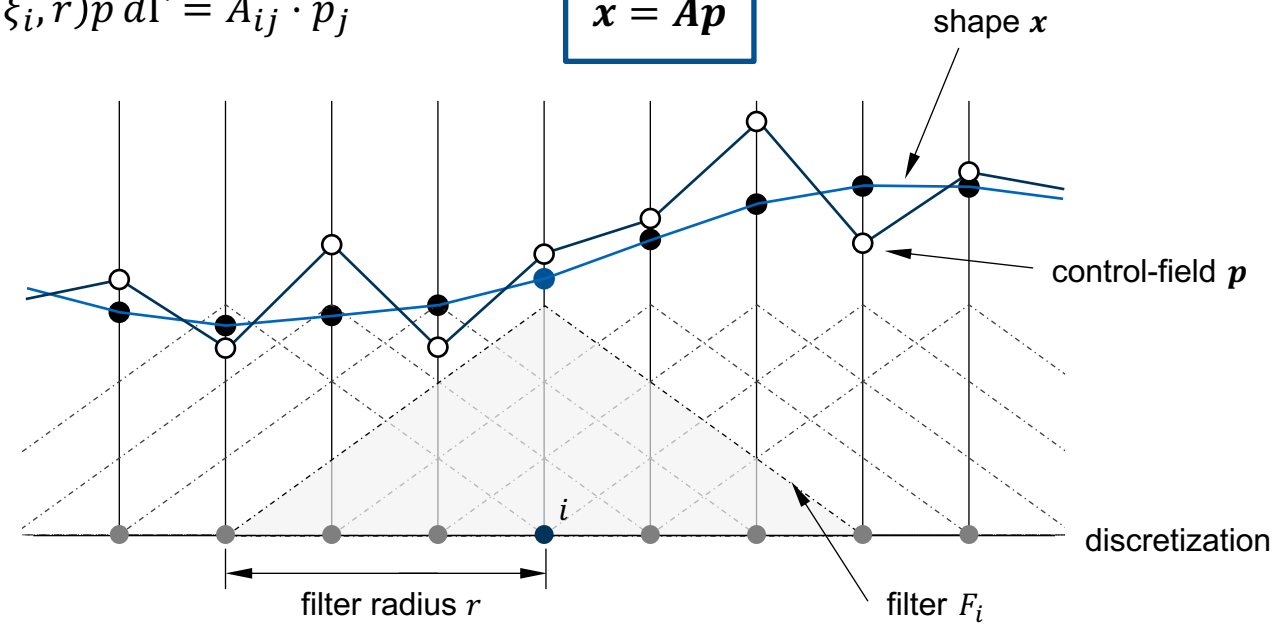
Figures from [Schwarz]



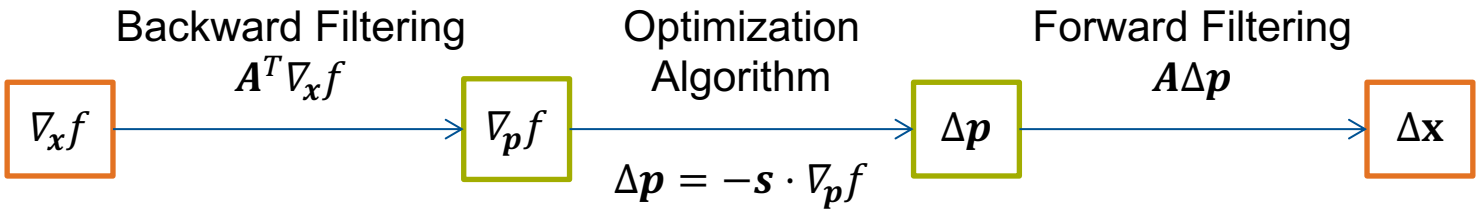
Vertex Morphing

$$x_i = \int F(\xi, \xi_i, r) p \, d\Gamma = A_{ij} \cdot p_j$$

$$\boldsymbol{x = Ap}$$



Vertex Morphing

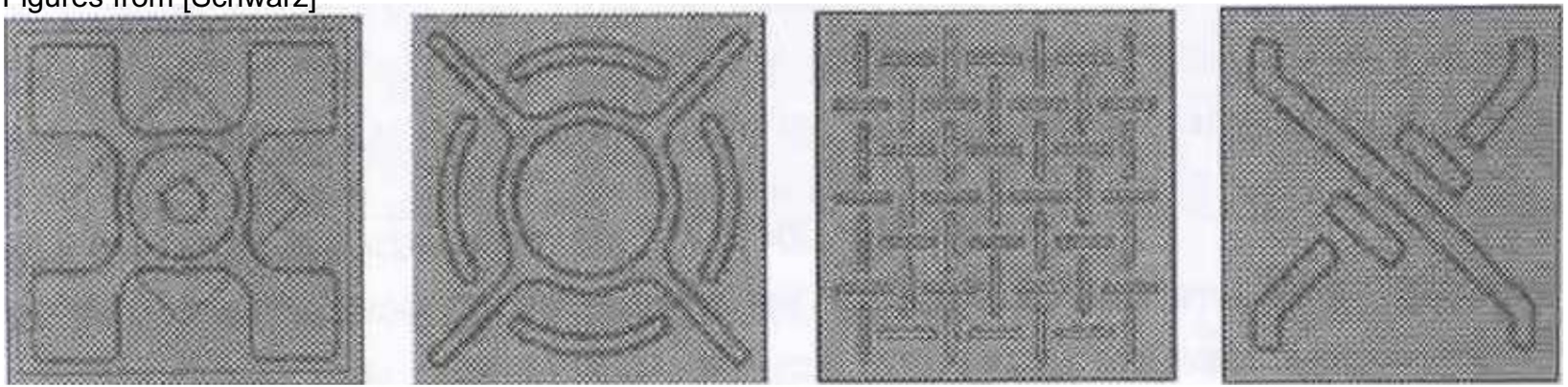


Detailed study: [Hojjat] [Bletzinger]

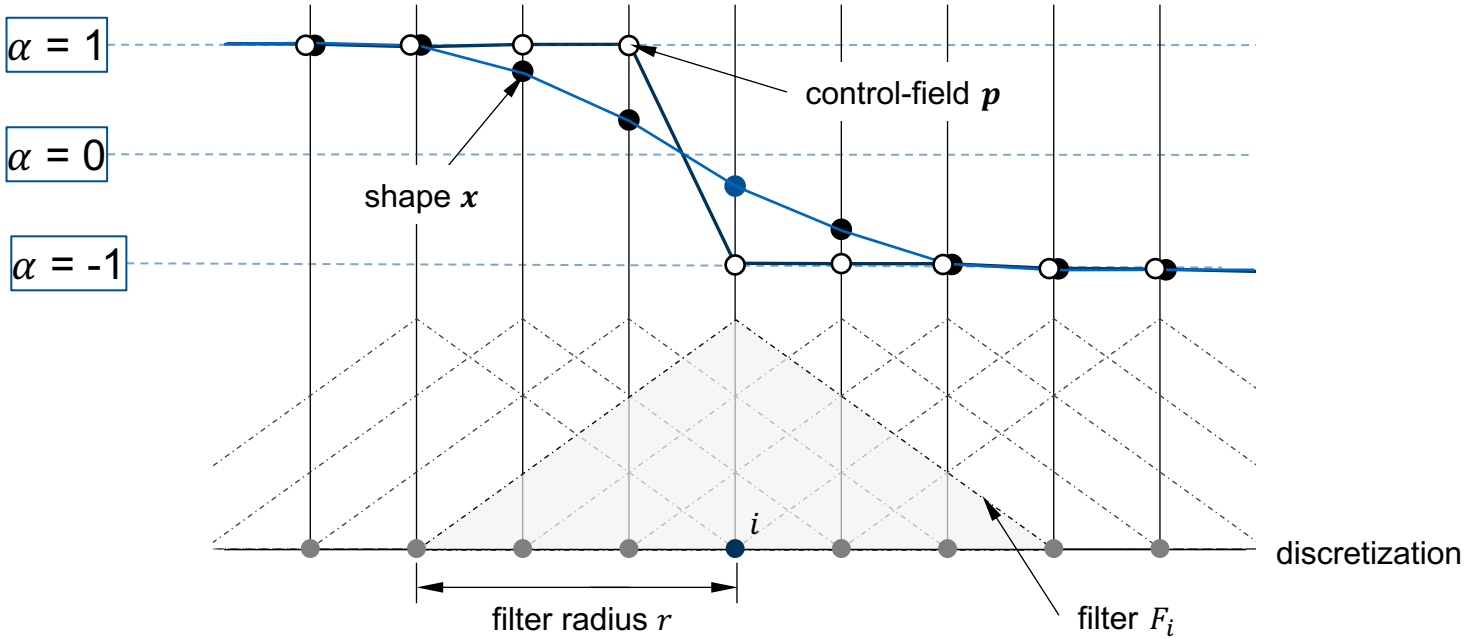
Bead Parameterization

- Start from initial flat plate
- Updates only in defined „bead direction“
- Bead parameter α goes from -1 (lower bound) to 1 (upper bound)

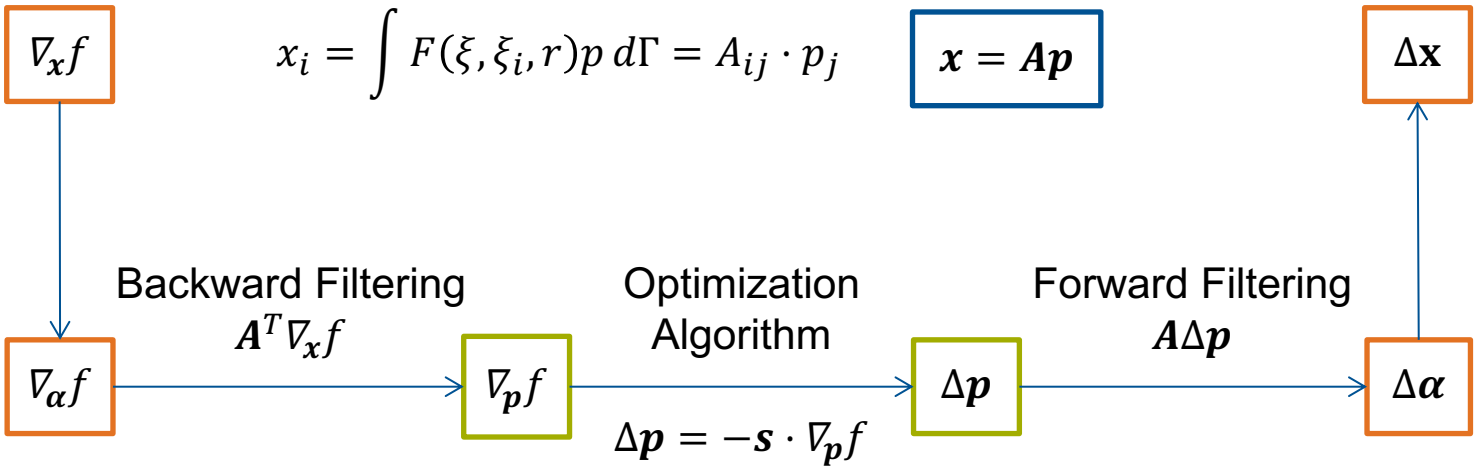
Figures from [Schwarz]



Bead Parameterization



Bead Parameterization

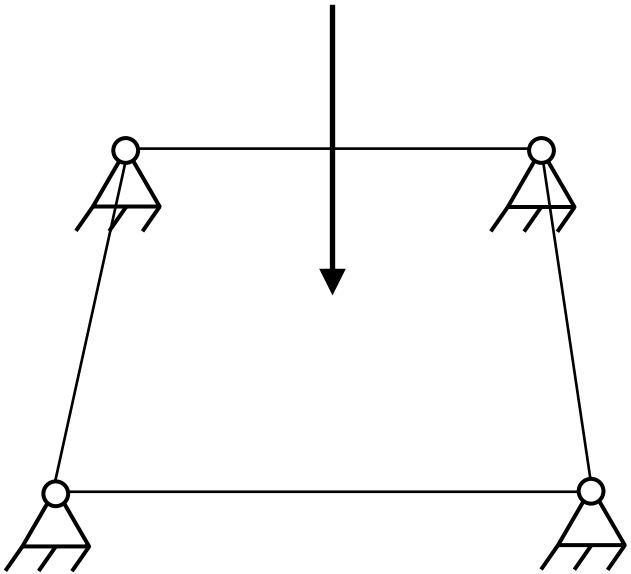


Penalty term forces control values to go to either +1 or -1:

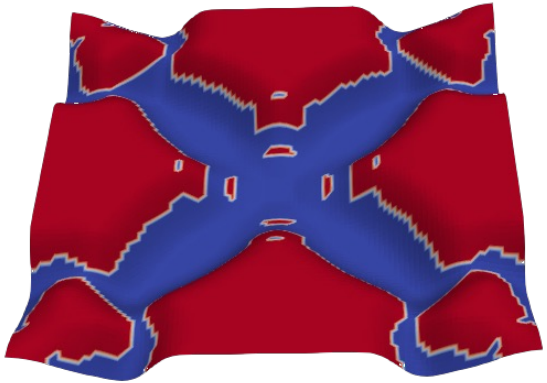
$\sigma = -p^2 + 1$

Bead Parameterization

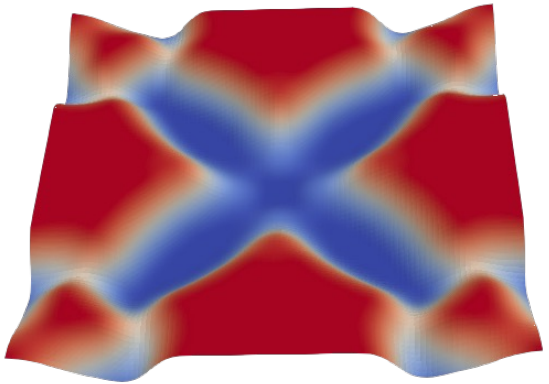
Initially flat plate (α=0, p=0)



Discrete alpha field in control space (p=±1)

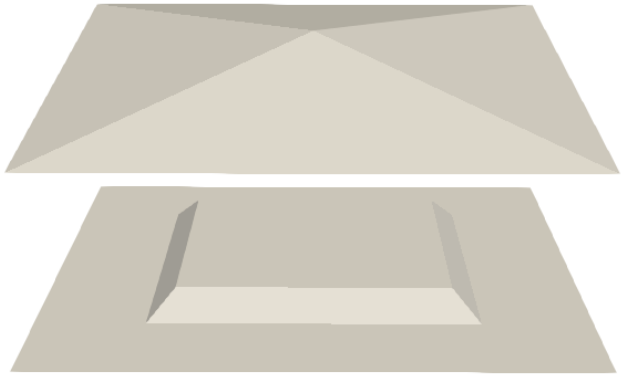


Filtered alpha field



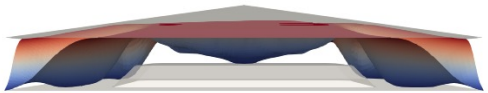
Variable Bead Height

- Starting from initial flat plate
- Using bounding geometries

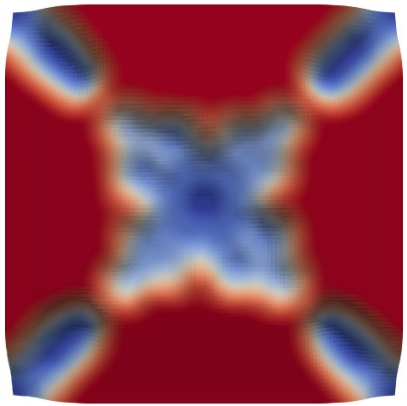


Variable Bead Height

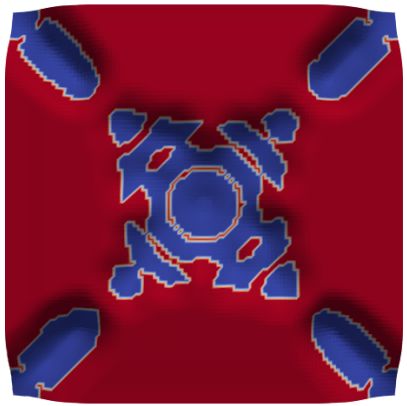
Filtered alpha field
side view



Filtered alpha field
top view

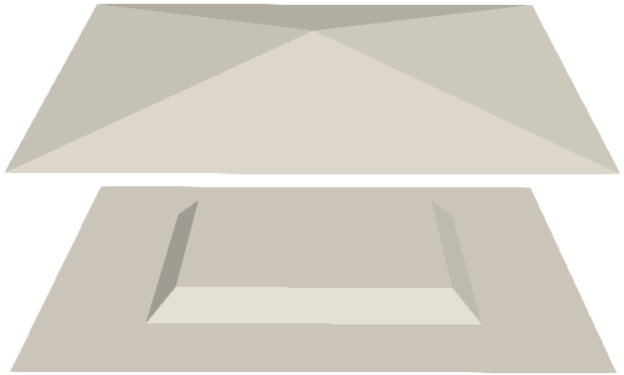


Discrete alpha field in
control space (p=±1)

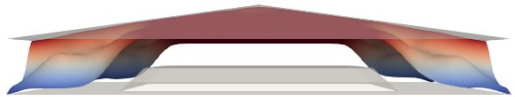


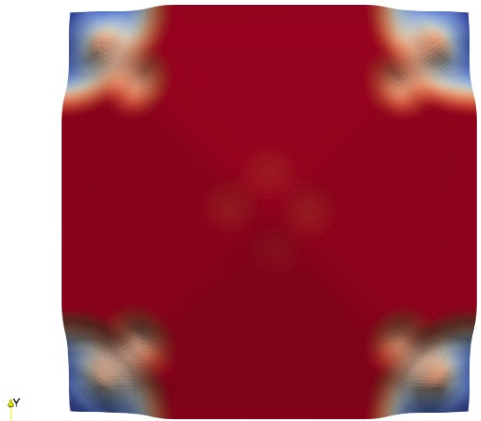
Variable Bead Height

Starting from an initially non-flat geometry



Variable Bead Height





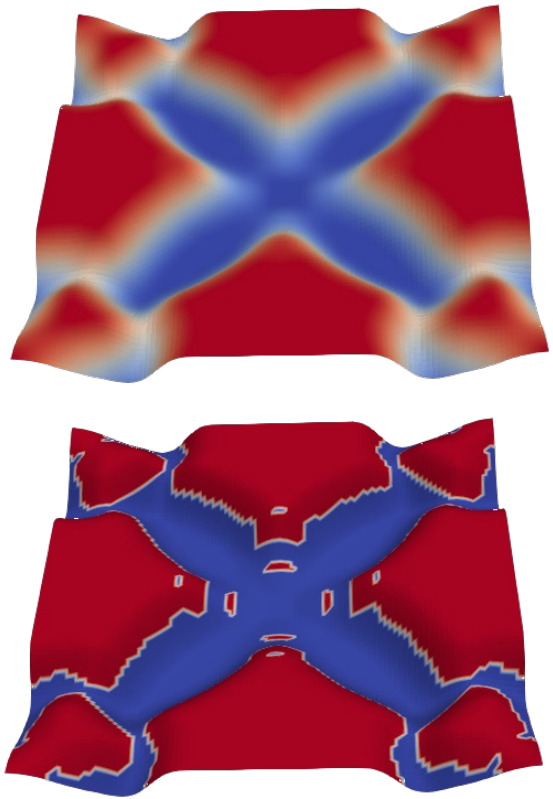
Conclusion / Outlook

Bead patterns have been realized with

- Vertex Morphing
- Parameterization with bead parameter α
- Penalty
- Variable bead heights
- Initially curved geometry

Outlook:

- Avoid small bead “islands“
- Create feature based beads



References

1. M. Hojjat, E. Stavropoulou, K.-U. Bletzinger: *The Vertex Morphing method for node-based shape optimization*, Computer Methods in Applied Mechanics and Engineering, 268:494-513, 2014.
2. K.-U. Bletzinger, Kai-Uwe: *A consistent frame for sensitivity filtering and the vertex assigned morphing of optimal shape*, Structural and Multidisciplinary Optimization, 49:873-895, 2014.
3. F. Daoud: *Formoptimierung von Freiformschalen: Mathematische Algorithmen und Filtertechniken*. Shaker, 2005.
4. D. Schwarz: *Gestaltung optimierter Sickenbilder für flächige Strukturen unter Einsatz numerischer Optimierungsverfahren*. Doktorarbeit, Institut, für Kraftfahrwesen Aachen, 2003.

Thank you for your attention!

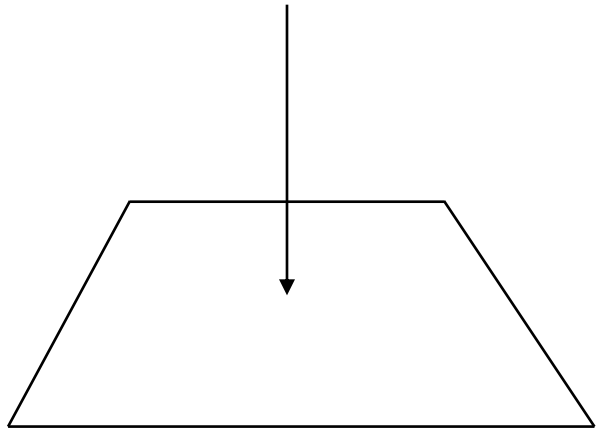
Bead Parameterization Approach

Example:

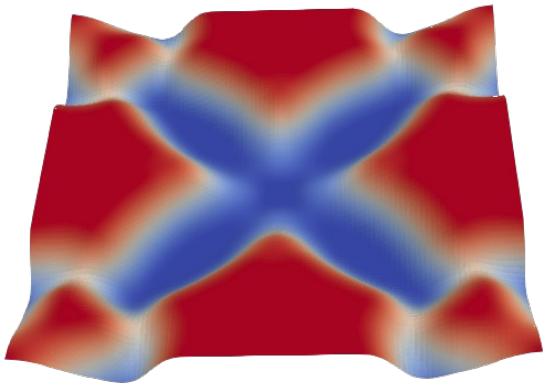
Initial design: flat plate

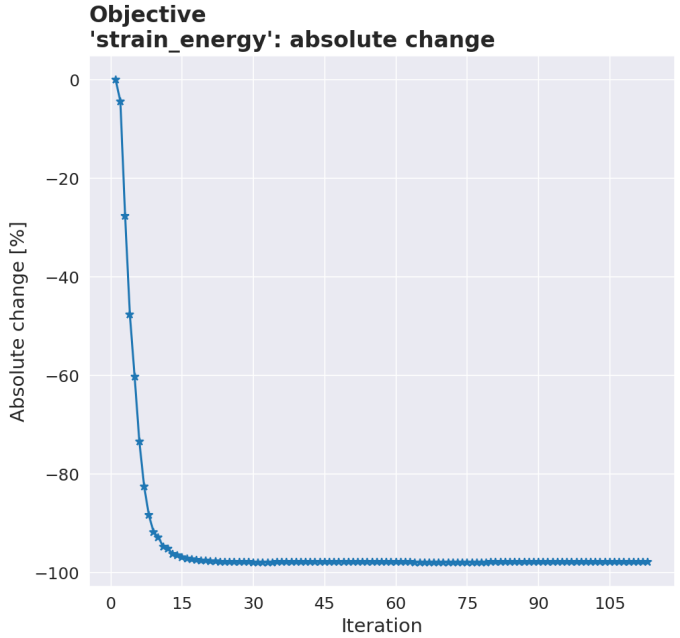
- Dimensions: 100 x 100
- Bead height: 5
- Filter radius: 7.5
- Thickness: 1
- Bead direction: vertical

Minimize compliance (no constraint)

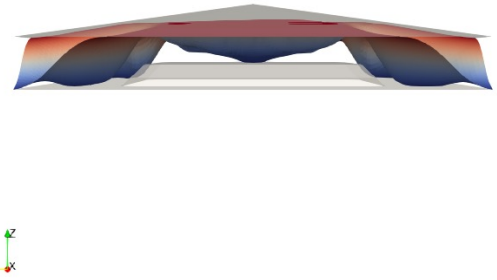


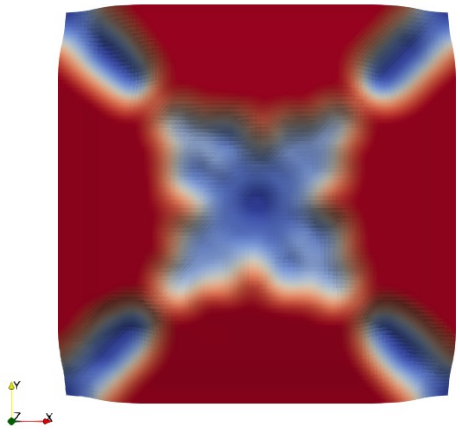
Performance original bead parameterization

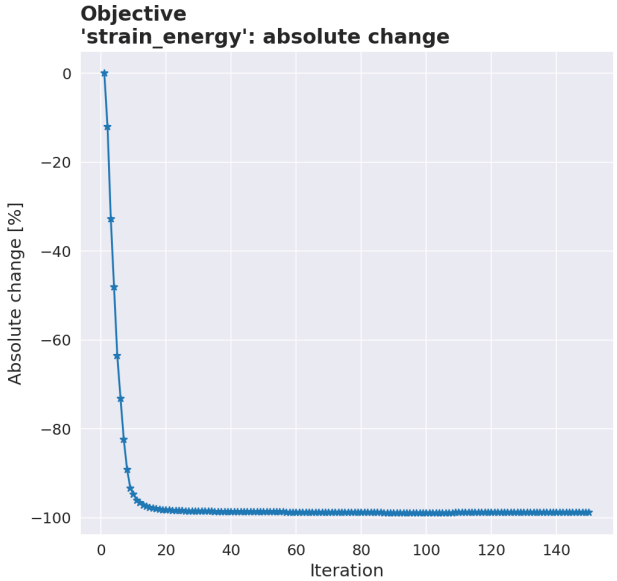




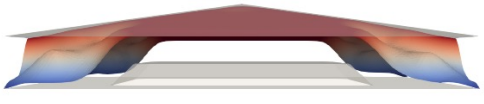
Performance variable bead height parameterization

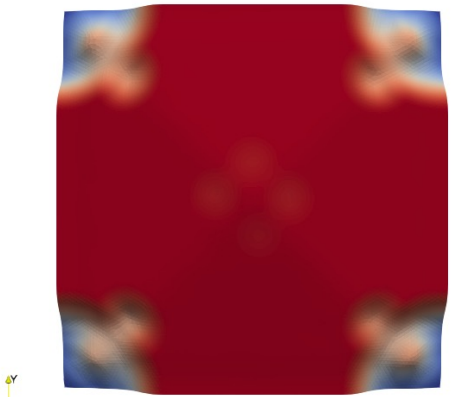


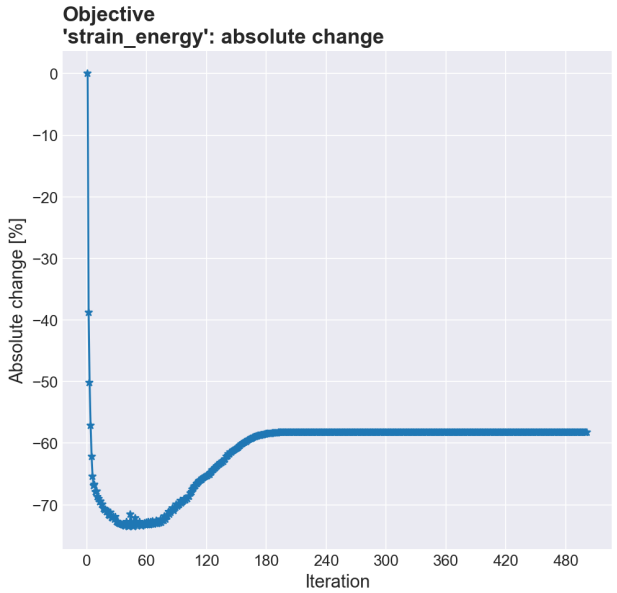




Performance initially curved geometry







Vertex Morphing

Filtering technique
Image with standard/simple optimization workflow (raw sensitivities – opt algo – design update)
Maps the sensitivities from design space to „control space“ and maps the „control updates“ back to design space (figure)

Use control design variables p that describe the actual geometry x (shape parameterization) related by: x = A(p) with A the transformation (or scaling) matrix from the design (control) field s to the actual geometry x.

Vertex Morphing

Notes from Majids Dissertation:

- The essence of the method is the filtering of the sensitivity field as well as the shape update vector by help of a suitable parametrization.
- The filtering (regularization) operations are derived consistently from the chain rule of differentiation
- Elaborate variable transformation enhanced with a suitable dimensional reduction for mesh quality regularization.
- explicit