OptCuts: Joint Optimization of Surface Cuts and Parameterization

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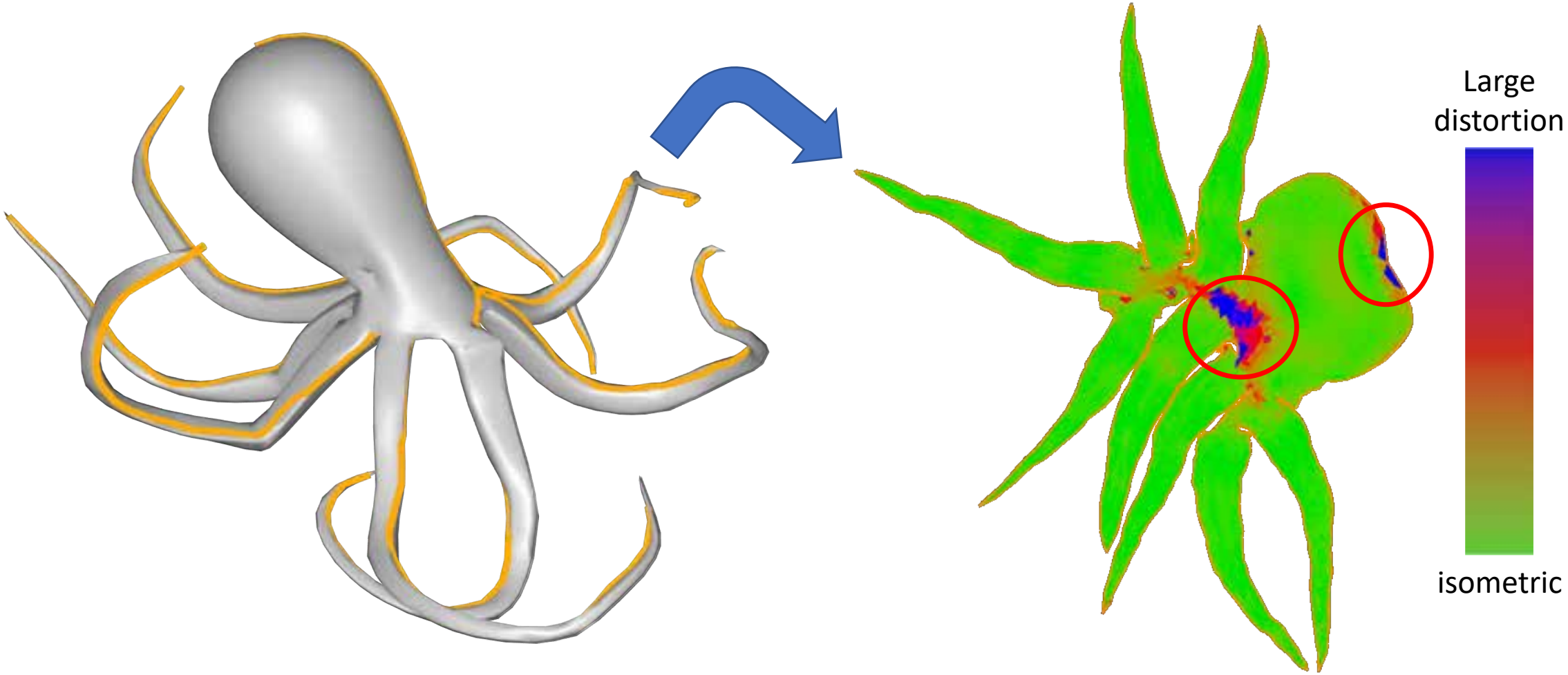
UV Unwrapping



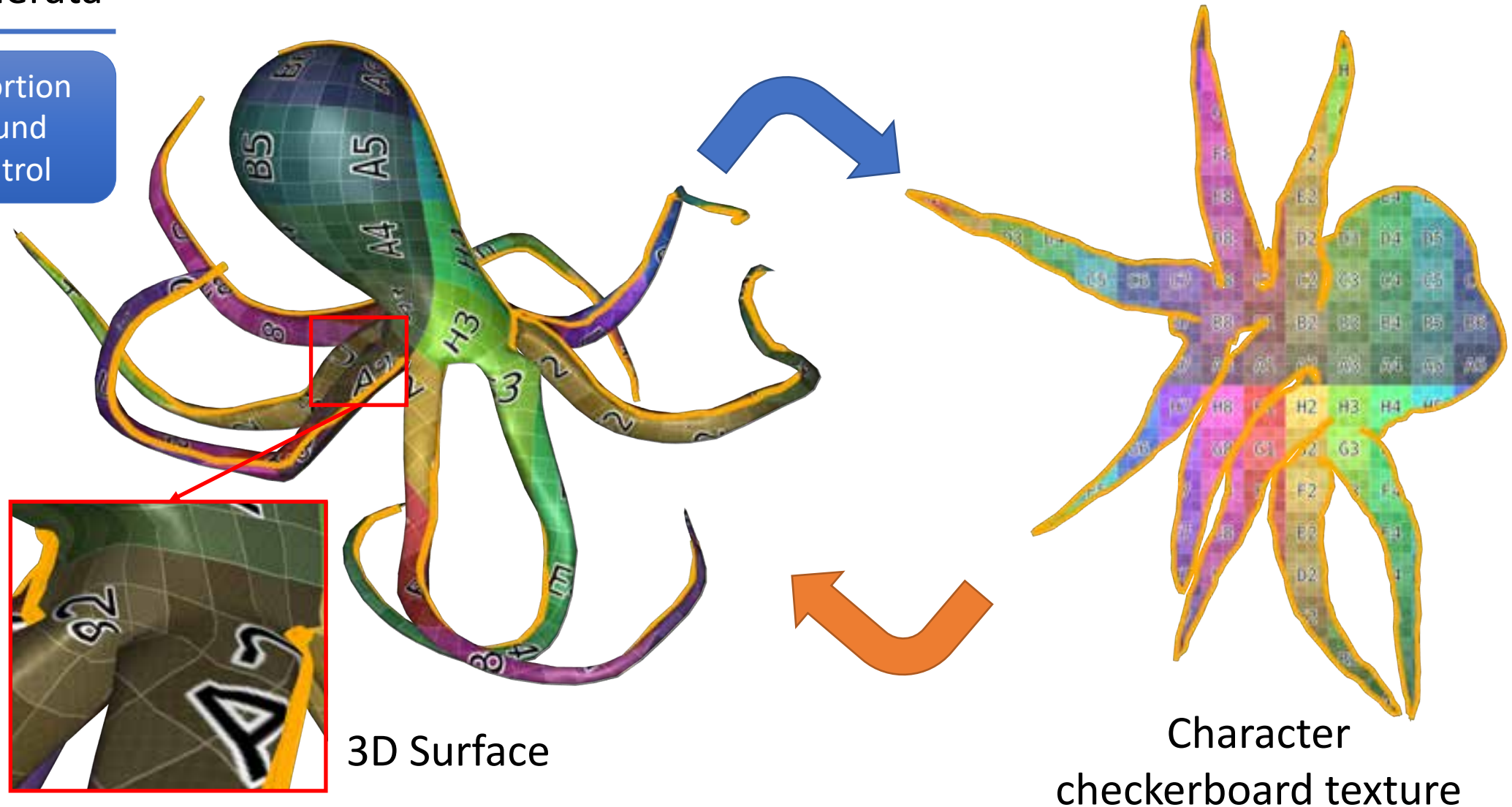
3D Surface

UV Map from ZBrush

Texture Mapping

Desiderata

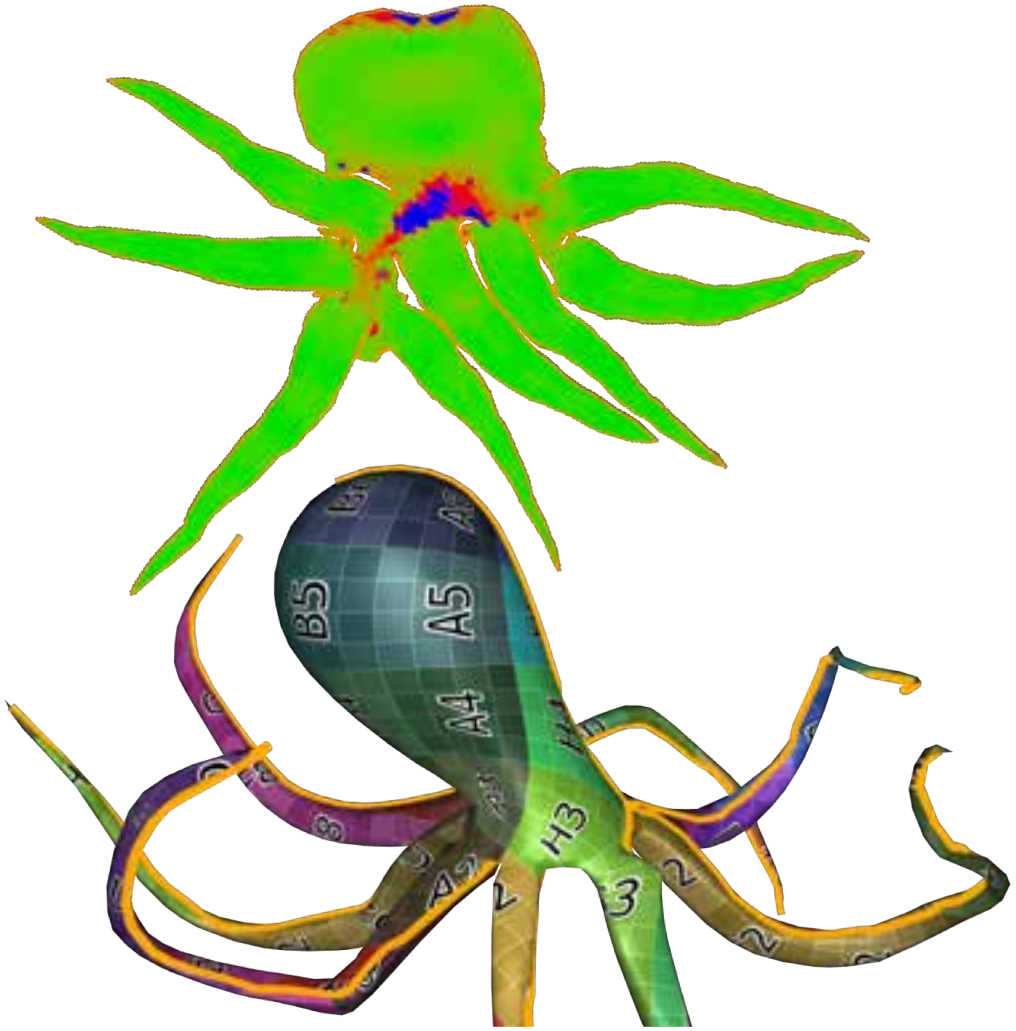
Distortion bound control



Distortion v.s. Seams

Desiderata

- Distortion bound control
- Short seams



short seam

large distortion

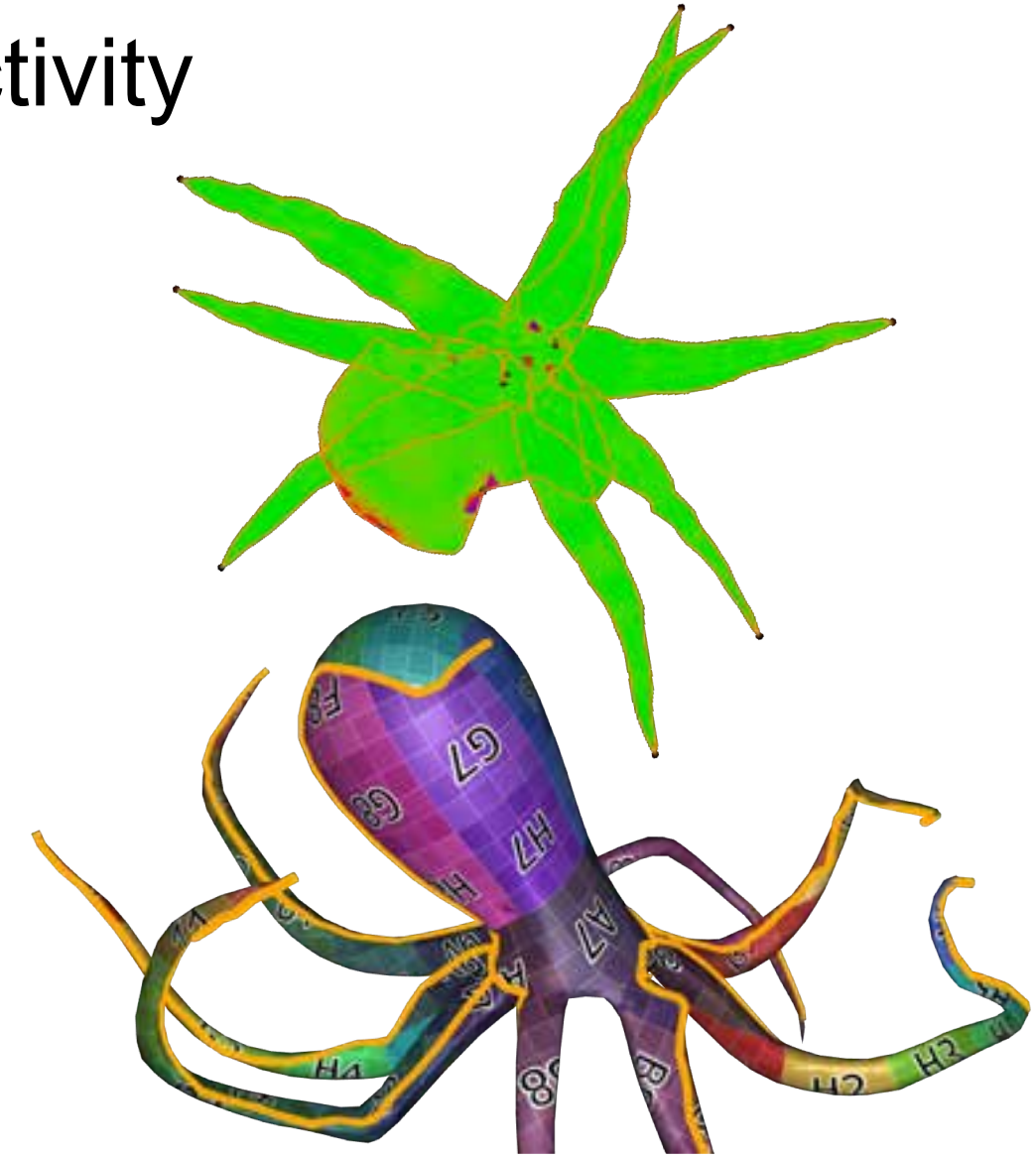
long seam

small distortion

Bijectivity

Desiderata

- Distortion bound control
- Short seams
- Bijective mapping



short seam

with overlaps

long seam

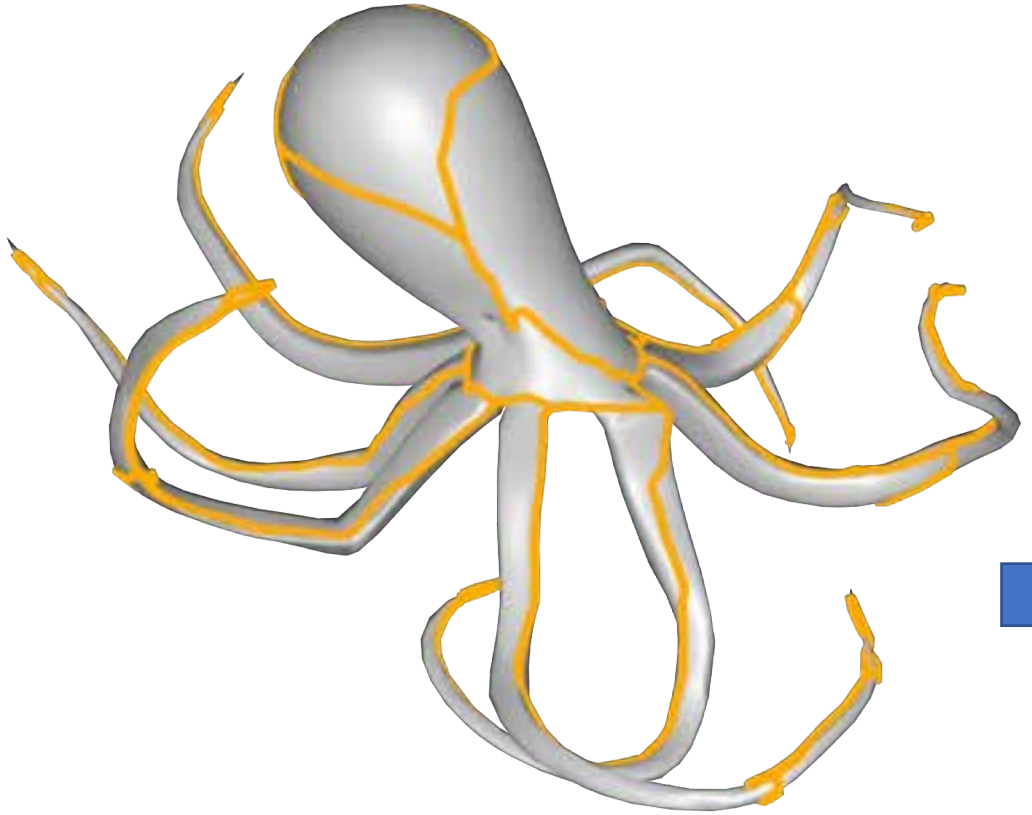
bijective

Traditional Parameterization Methods

Desiderata

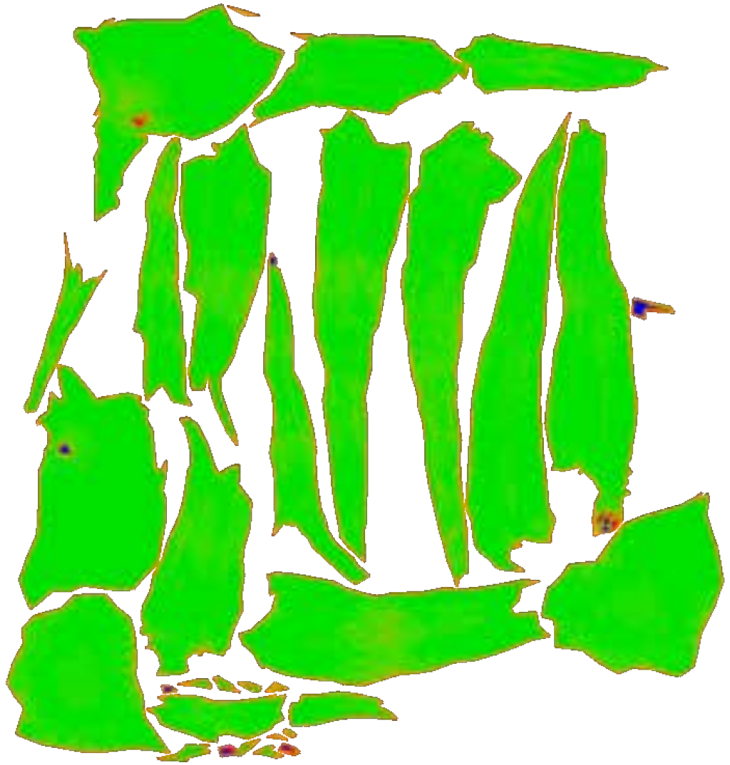
- Distortion bound control
- Short seams
- Bijective mapping
- No tuning of parameters

Step 1: Seam Placement



Topological algorithms
e.g. [Zhou et al. 2004], [Julius et al. 2005], [Sheffer and Hart 2002], etc.

Step 2: Distortion Minimization



Geometric Techniques
e.g. [Sheffer et al. 2005], [Liu et al. 2008], [Smith and Schaefer 2015], etc.

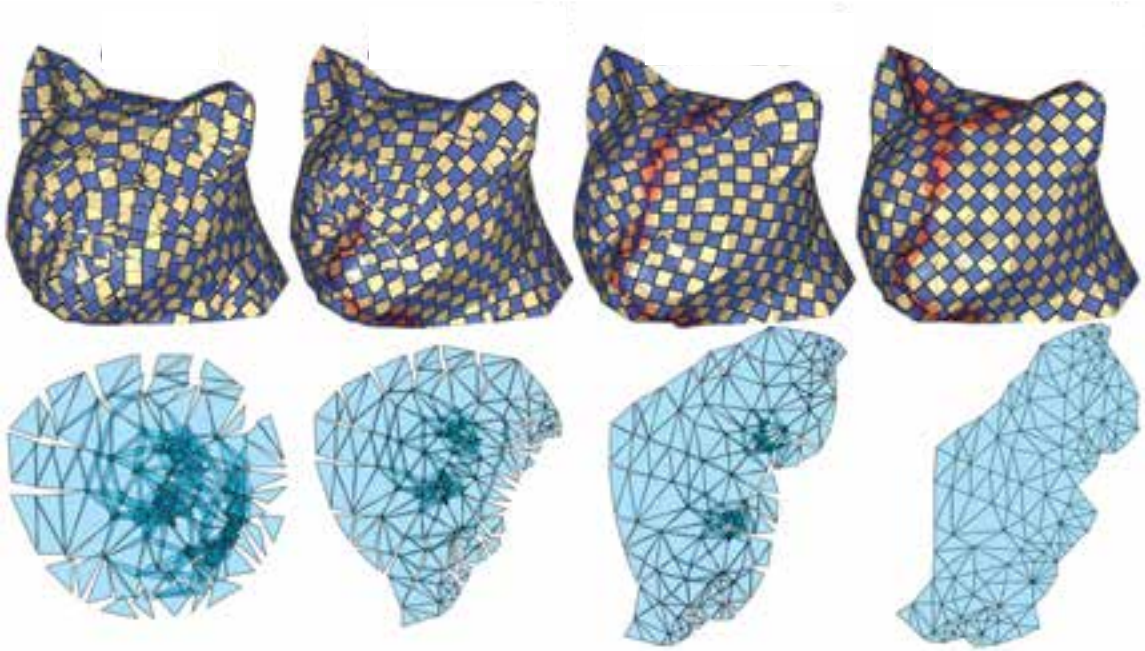
AutoCuts [Poranne et al. 2017]

AutoCuts

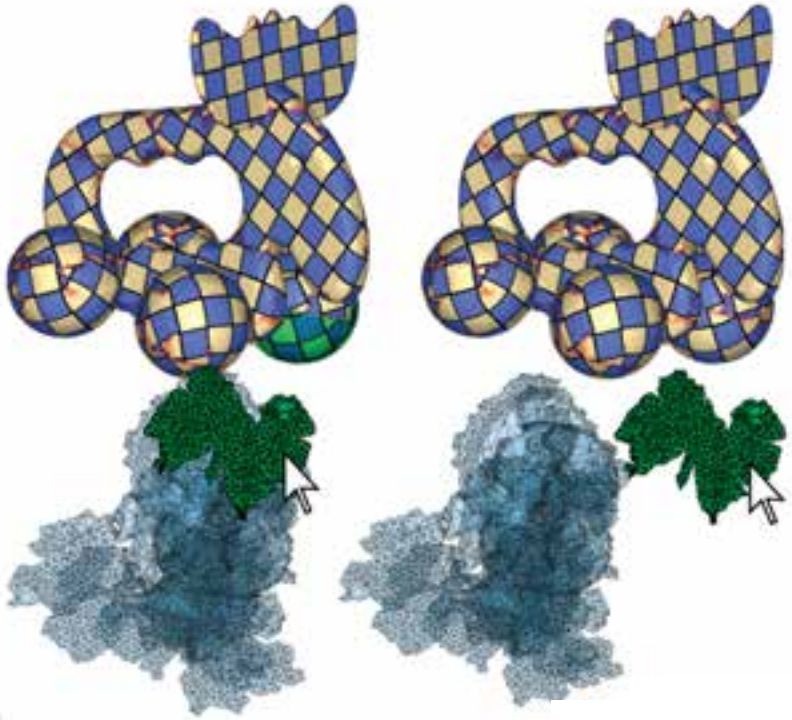
- Distortion bound control
- Short seams ✓
- Bijective mapping
- No tuning of parameters

distortion seam

$$\min_{X} E(X) = \min_{X} (1-\lambda) D(X) + \lambda S(X)$$



better seam approximation, less smooth problem



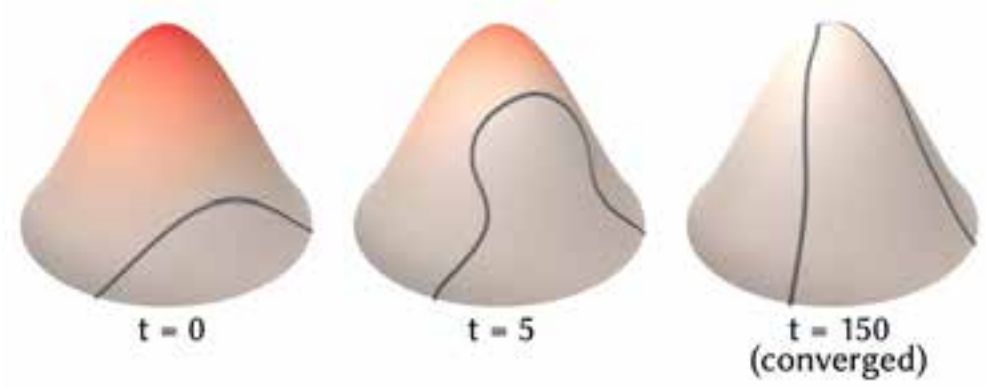
user assistance to avoid overlaps

Variational Surface Cutting [Sharp and Crane 2018]

VSC

- Distortion bound control
- Short seams ✓
- Bijective mapping
- No tuning of parameters

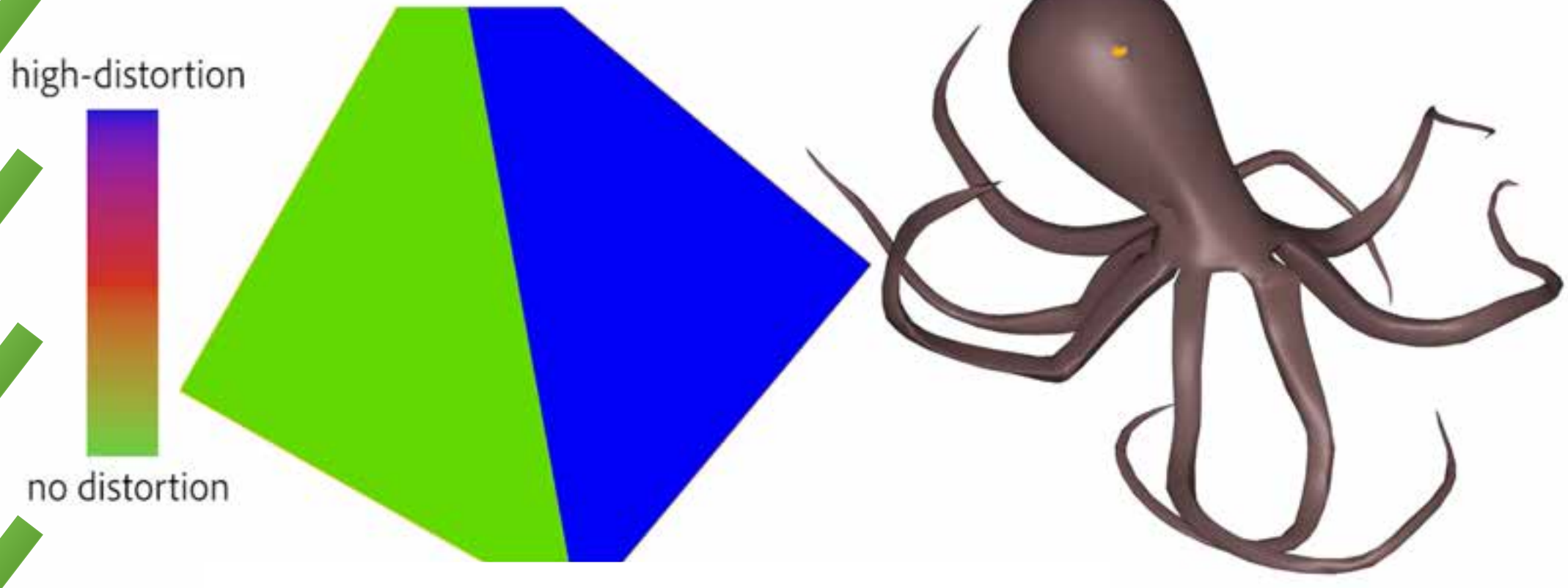
$$\frac{d}{dt}\gamma = \left(\frac{\partial u}{\partial n}\right)^2 n,$$



OptCuts

OptCuts

- Distortion bound control ✓
- Short seams ✓
- Bijective mapping ✓
- No tuning of parameters ✓



OptCuts Model Problem

distortion seam length

E_d v.s. E_s

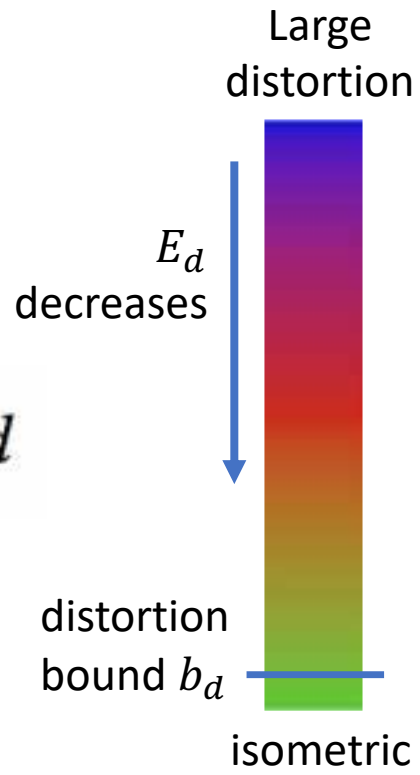
???

seam length distortion

$$\min_{T,U} E_s(T) \quad s.t. \quad E_d(T,U) \leq b_d$$

UV topology

UV coordinates



OptCuts Saddle Point Problem

$$\min_{T,U} E_s(T) \quad s.t. \quad E_d(T,U) \leq b_d$$

$$\min_{T,U} \max_{\lambda \geq 0} L(T,U,\lambda) = E_s(T) + \lambda(E_d(T,U) - b_d)$$

OptCuts Algorithm

Pipeline

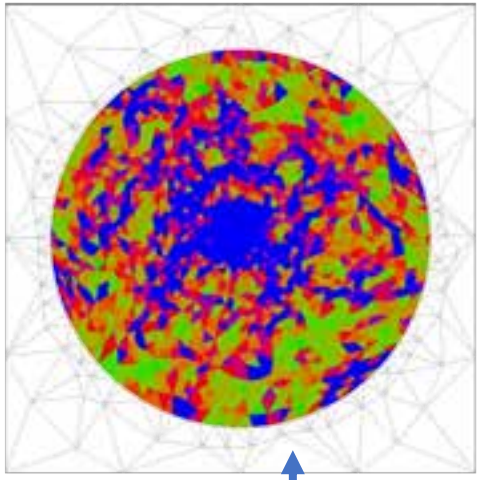
- Input: distortion bound b_d, initial UV map (T_0, U_0)
- Primal-Dual Algorithm

dual step

primal step

$$\min_{T,U} \max_{\lambda \geq 0} \tilde{L}(T, U, \lambda)$$

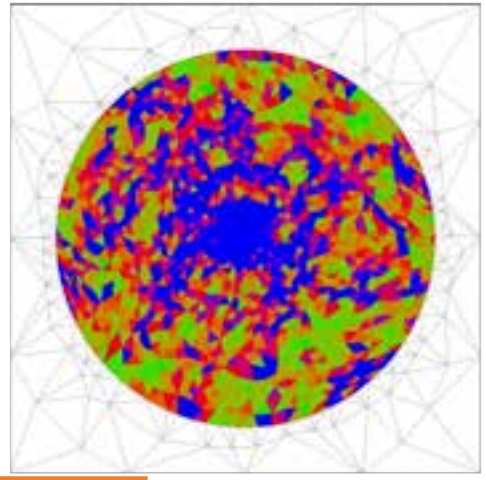
$$\lambda^k \leftarrow \max\left(0, \left(E_d(T^{k-1}, U^{k-1}) - b_d\right) + \lambda^{k-1}\right)$$



scaffolding triangles for global bijectivity [Jiang et al. 2017]

Pipeline

- Input: distortion bound b_d, initial UV map (T_0, U_0)
- Primal-Dual Algorithm



dual step

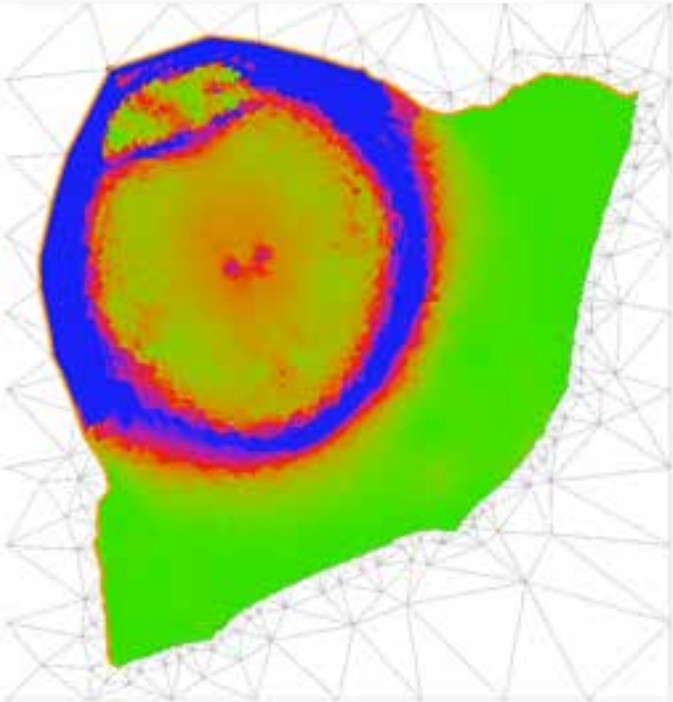
primal step

$$\min_{T,U} \max_{\lambda \geq 0} \tilde{L}(T, U, \lambda)$$

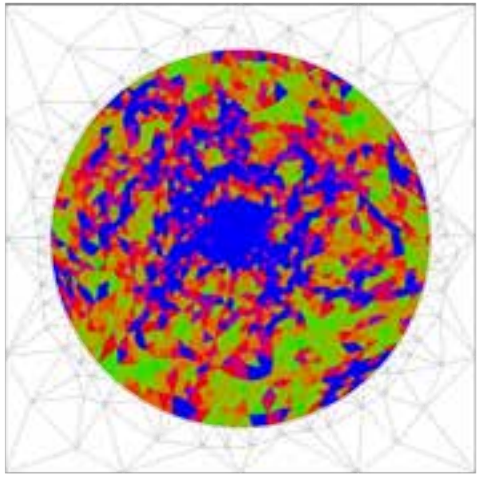
$$\min_{T,U} \max_{\lambda \geq 0} L(T, U, \lambda)$$

Geometry Step

Topology Step



Pipeline



- Input: distortion bound b_d, initial UV map (T_0, U_0)
- Primal-Dual Algorithm

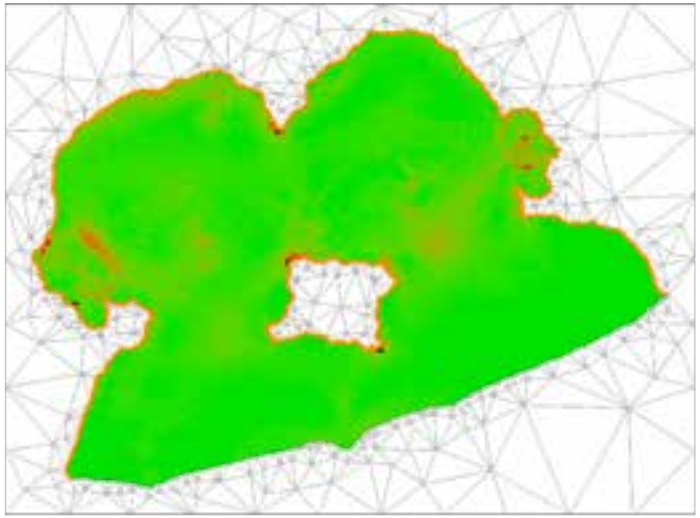
dual step

$$\min_{T,U} \max_{\lambda \geq 0} \tilde{L}(T, U, \lambda)$$

primal step

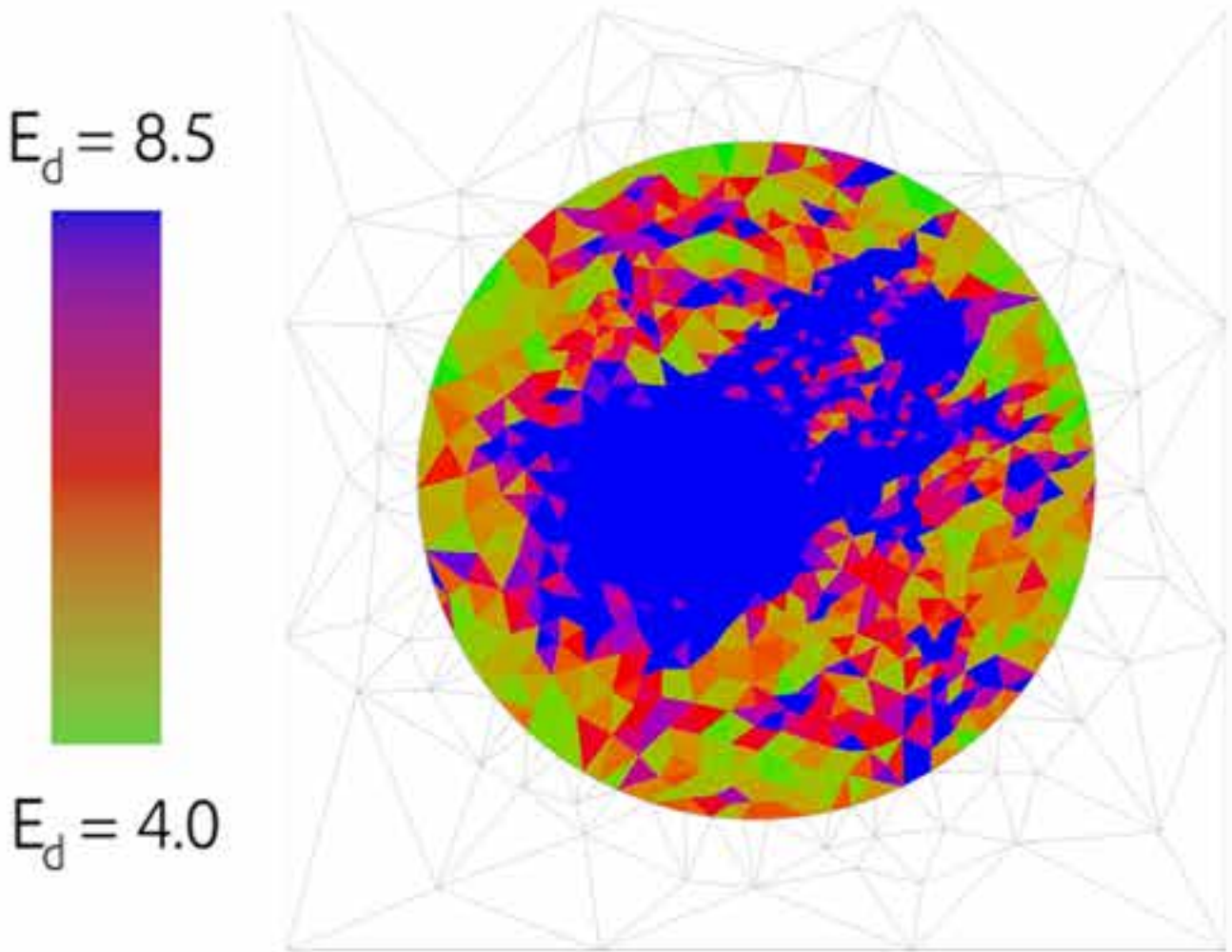
$$\min_{T,U} \max_{\lambda \geq 0} L(T, U, \lambda)$$

- Output: bijective UV map satisfying distortion bound with locally minimal seam length



Results

Chinese Lion Vertex #: 5036 $b_d = 4.1$



Benchmark

- 71 surfaces
- compare seam lengths under the same distortion

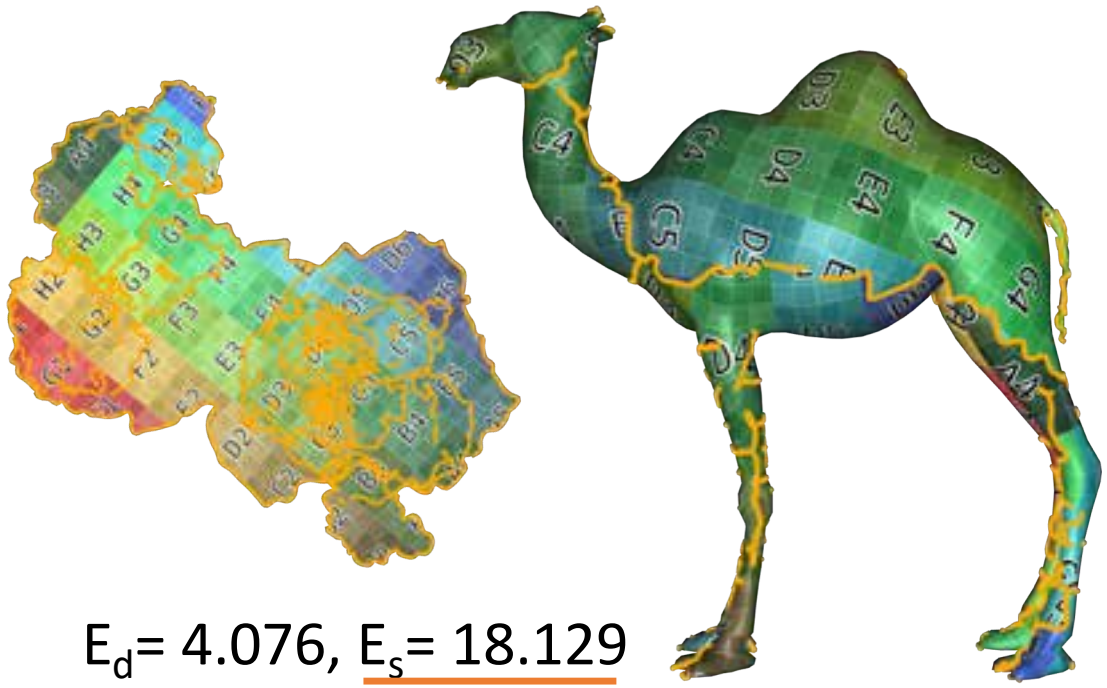
E_d= 4.197, E_s= 4.692

E_d= 4.099, E_s= 5.837

E_d= 4.049, E_s= 6.291

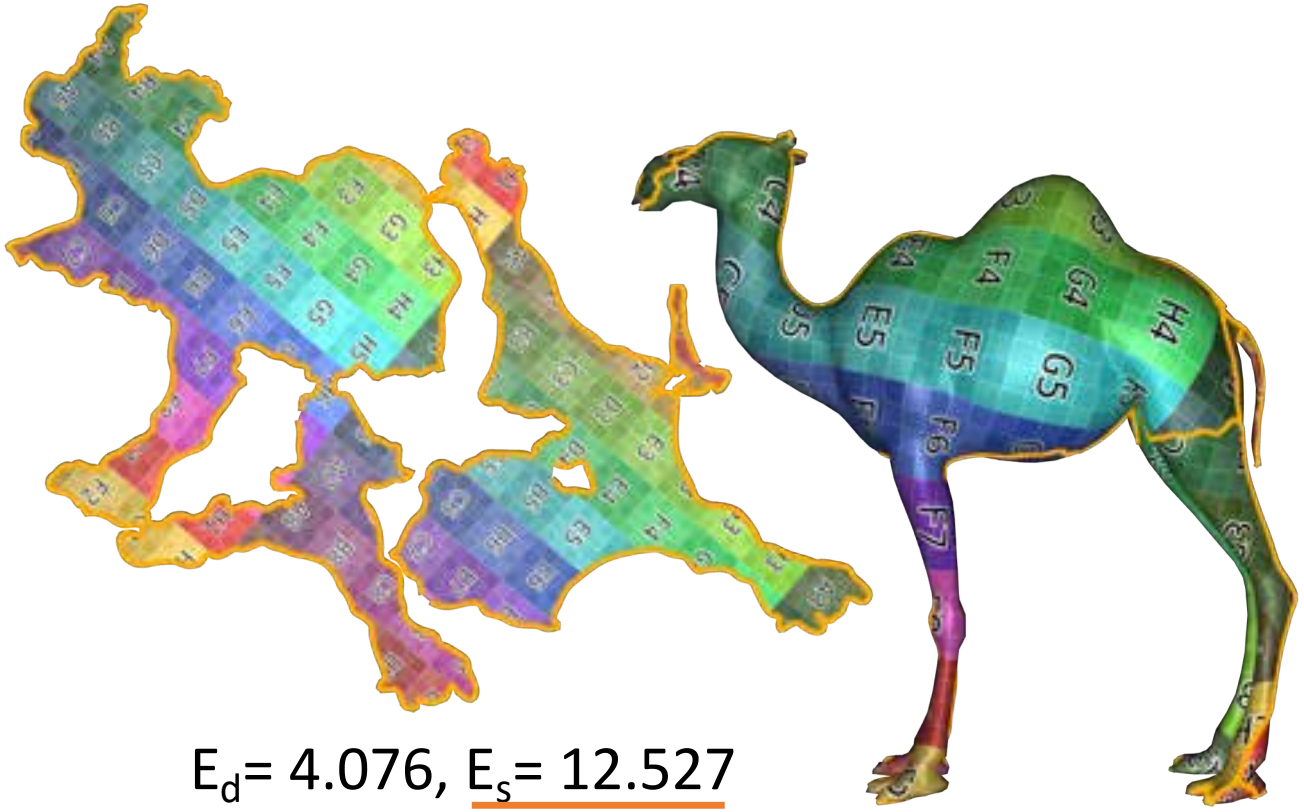
Comparison to AutoCuts

- set AutoCuts output E_d as input distortion bound b_d for OptCuts



E_d= 4.076, E_s= 18.129
time: 455s

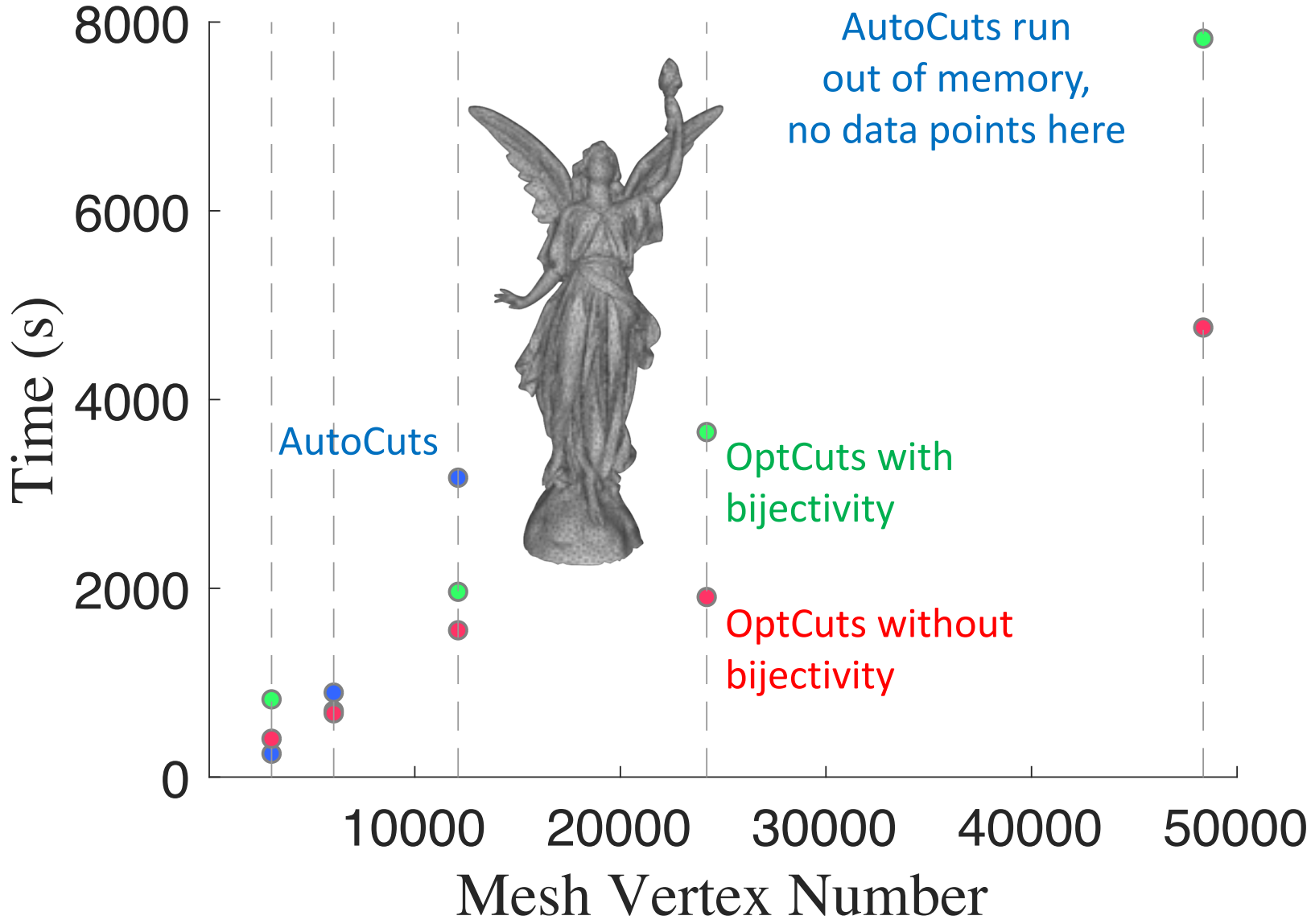
AutoCuts



E_d= 4.076, E_s= 12.527
time: 374s

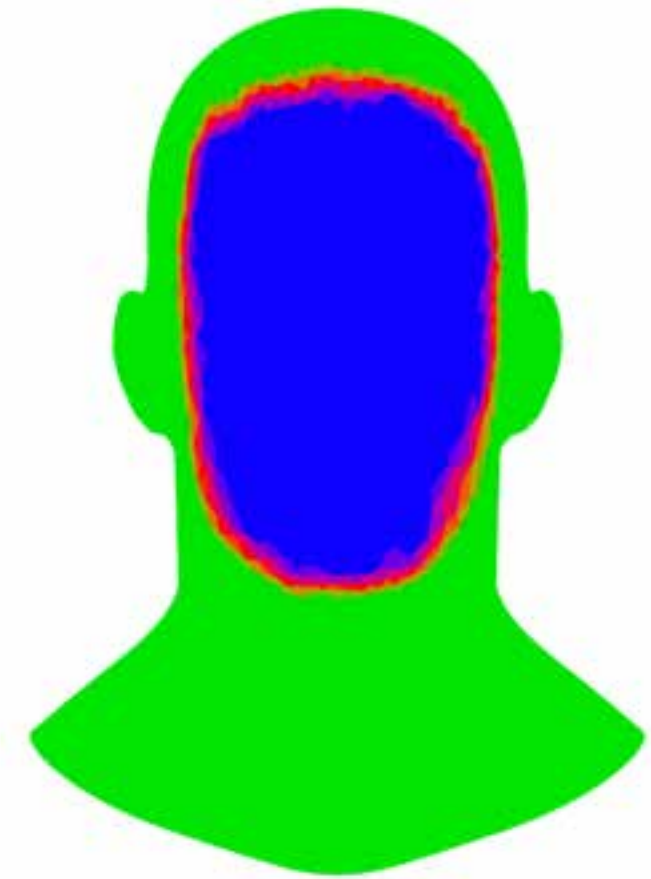
OptCuts with bijectivity

Scalability



Regional Seam Placement

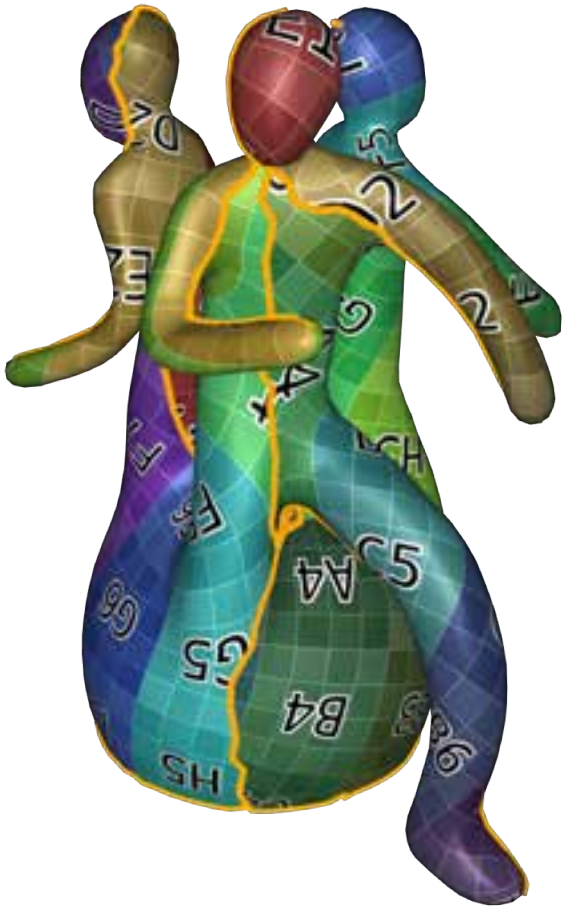
E_d = 4.100, E_s= 3.185
undirected OptCuts



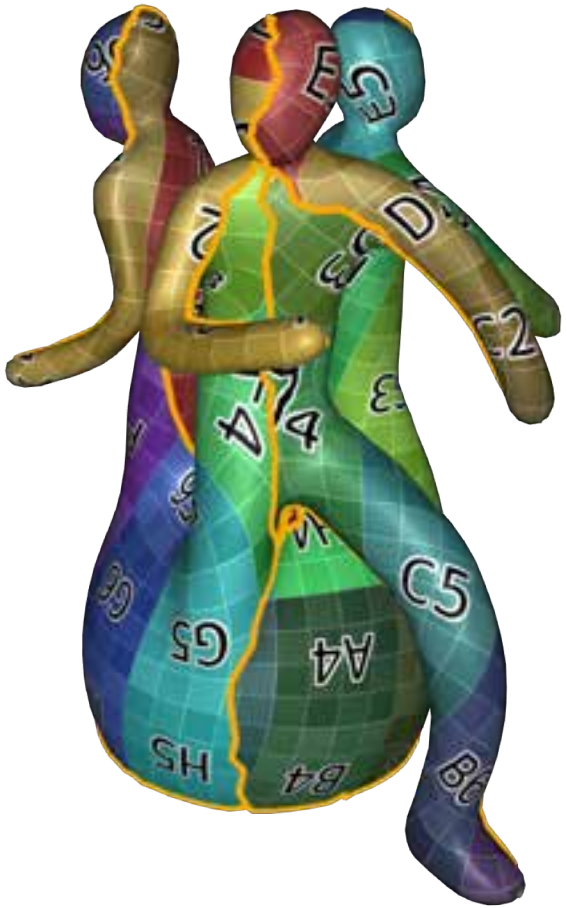
user painted
seam mask

E_d = 4.091, E_s= 3.740
directed OptCuts

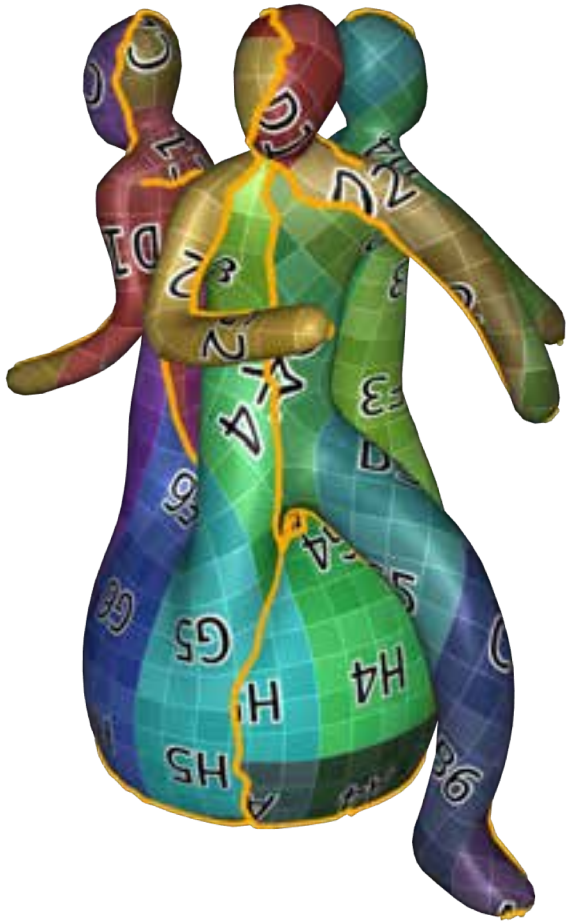
OptCuts Polishing



E_d= 4.146, E_s= 9.001
ZBrush



E_d= 4.146, E_s= 8.051
OptCuts Polishing
shorter seams



E_d= 4.099, E_s= 9.107
OptCuts Polishing
smaller distortion

Conclusions

OptCuts

- Distortion bound control ✓
- Short seams ✓
- Bijective mapping ✓
- No tuning of parameters ✓

- Constrained seam-length minimization model problem
- Coupled discrete-continuous descent

- Benchmark

- An optimization framework for UV parameterization
  - Regional seam placement
  - UV polishing
  - …

Future Work

- Seamless global parameterization
- Seam smoothness
- Packing efficiency
- Theoretical analysis on convergence and optimality

Thanks!

Results and source code (better implementation) coming soon:
http://www.cs.ubc.ca/labs/imager/tr/2018/OptCuts/

OptCuts: Joint Optimization of Surface Cuts and Parameterization

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