中国科学技术大学
University of Science and Technology of China

GAMES 301: 第6讲

参数化应用1 – Atlas生成

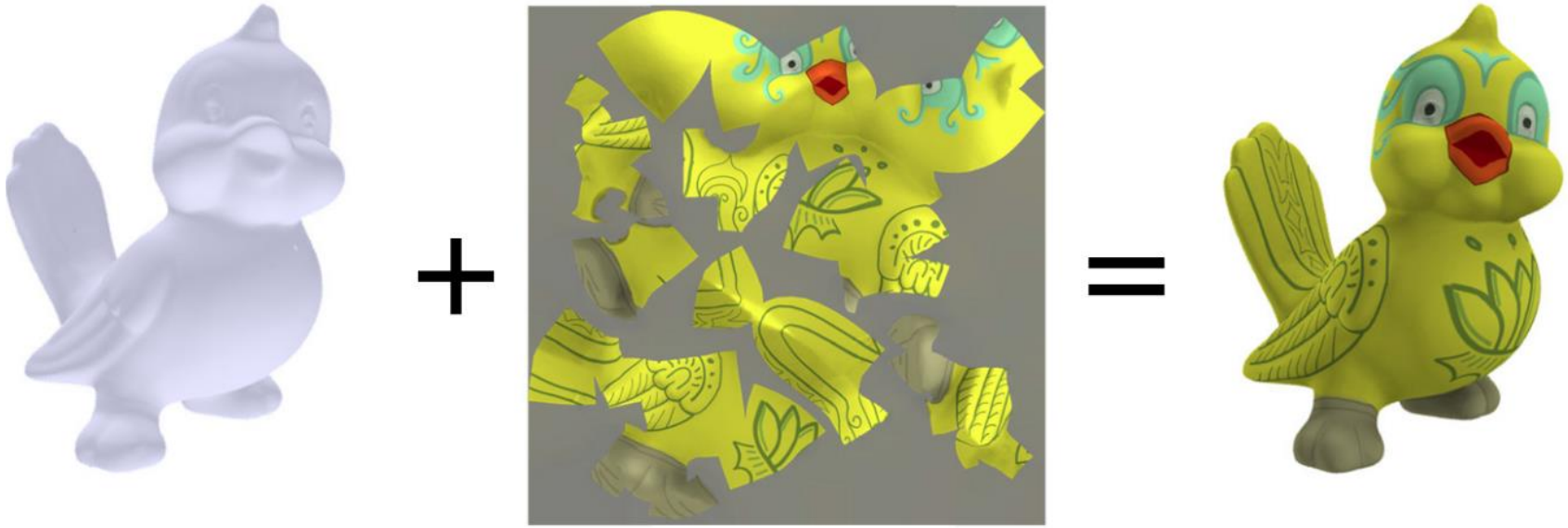
傅孝明
中国科学技术大学

Atlas generation

for scanned meshes

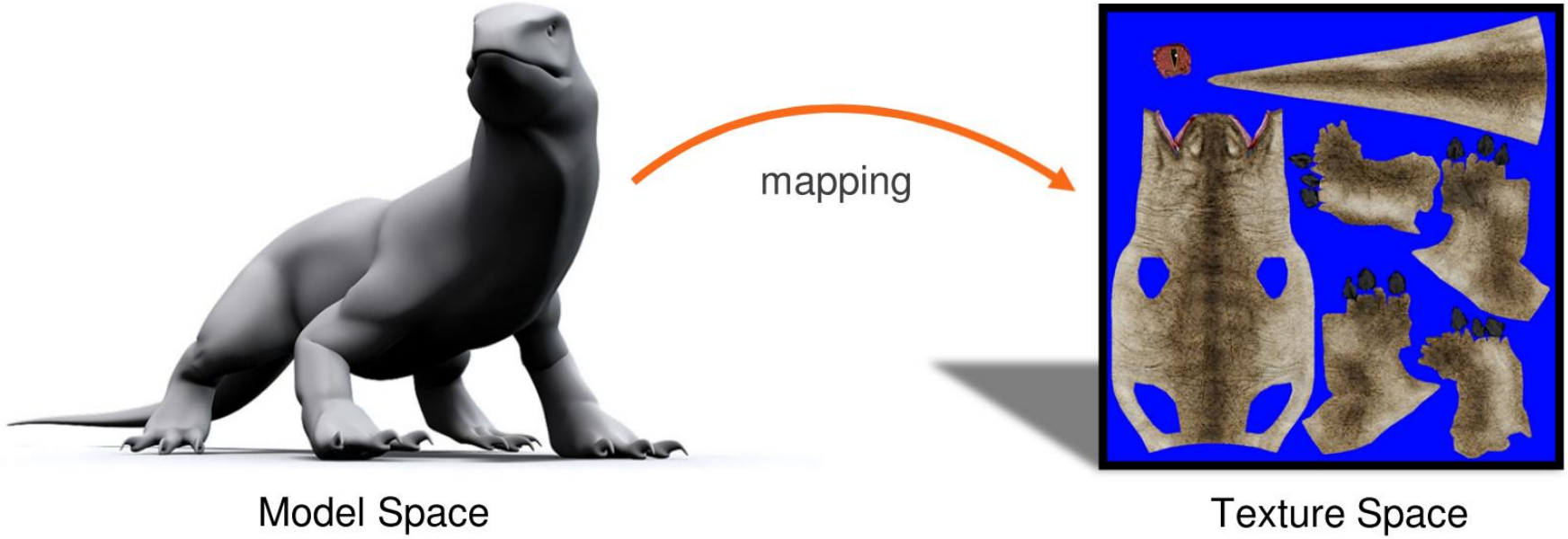
Texture Mapping

- Texture mapping is a method for defining high frequency detail, surface texture, or color information on a computer-generated graphic or 3D model.



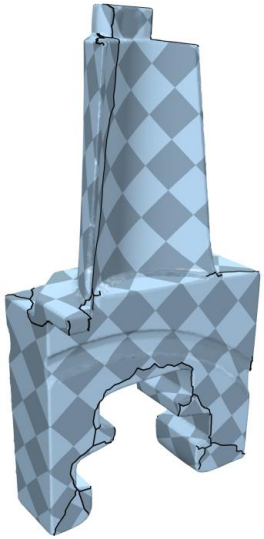
Atlas

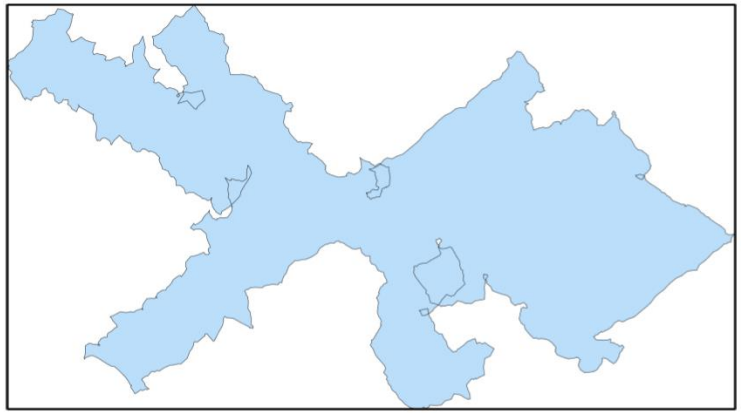
- Requires defining a **mapping** from the model space to the texture space.

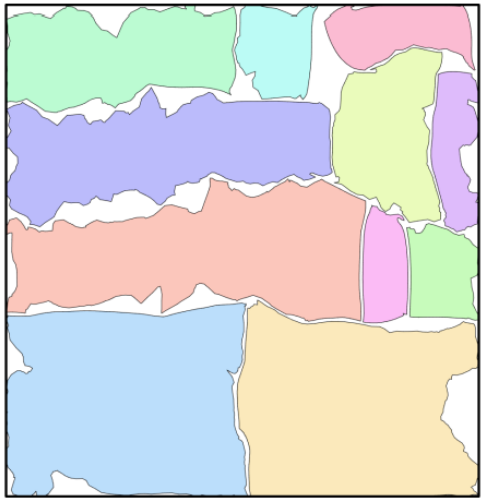


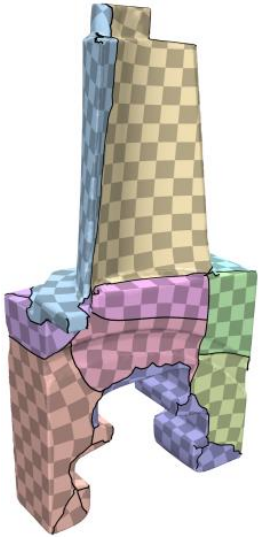
Generation process

Mesh cutting → Parameterizations → Packing



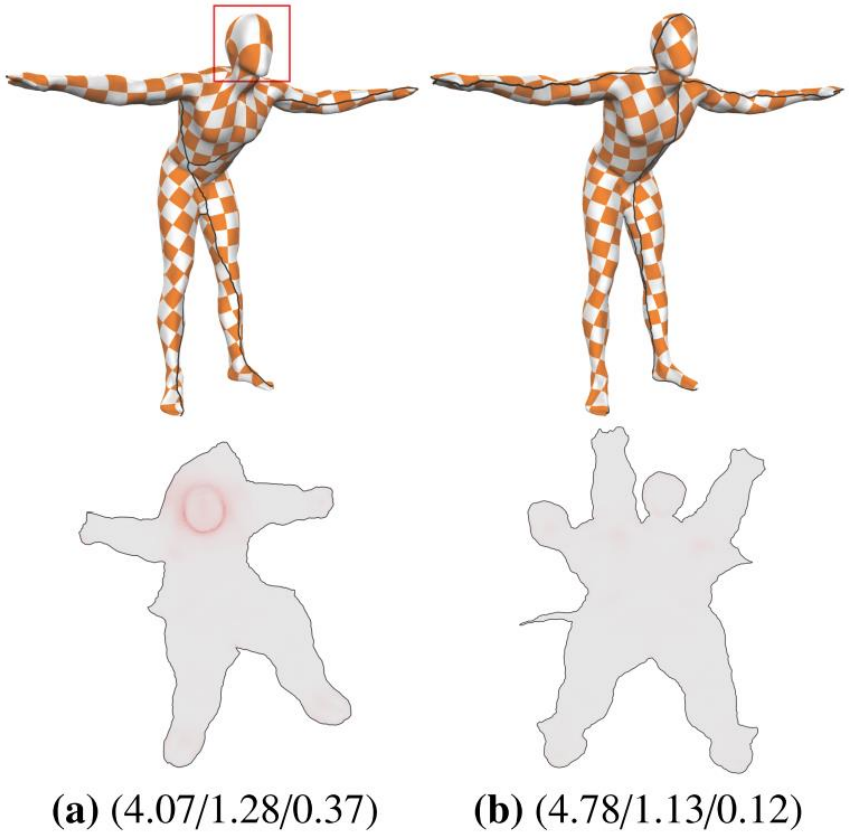






Mesh Cutting

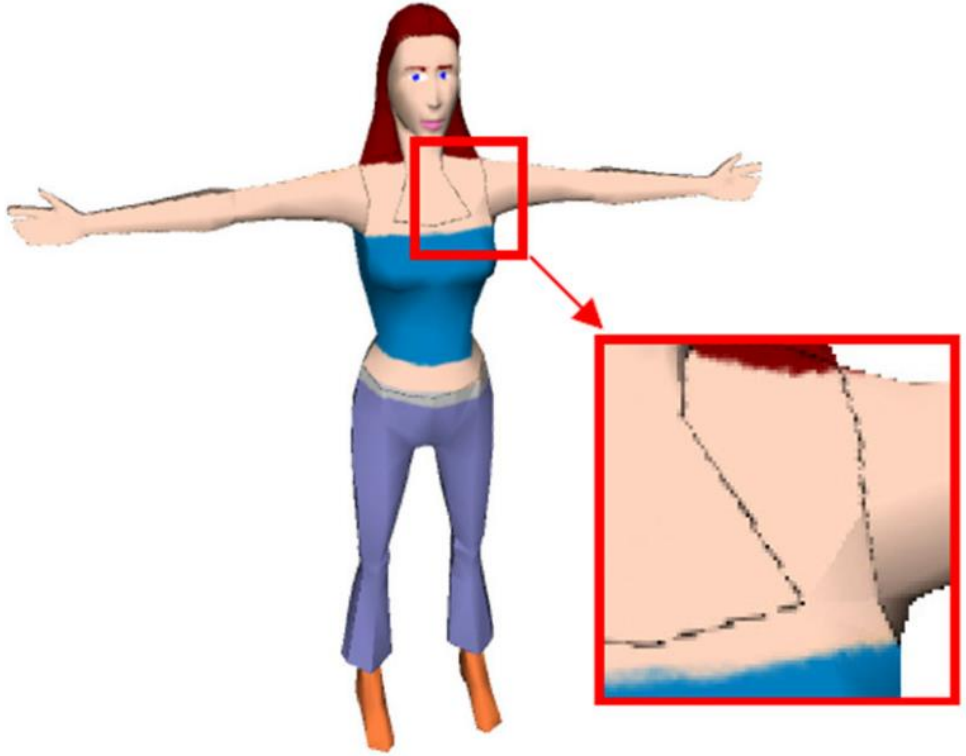
- Low distortion
- As short as possible length



(a) (4.07/1.28/0.37) **(b)** (4.78/1.13/0.12)

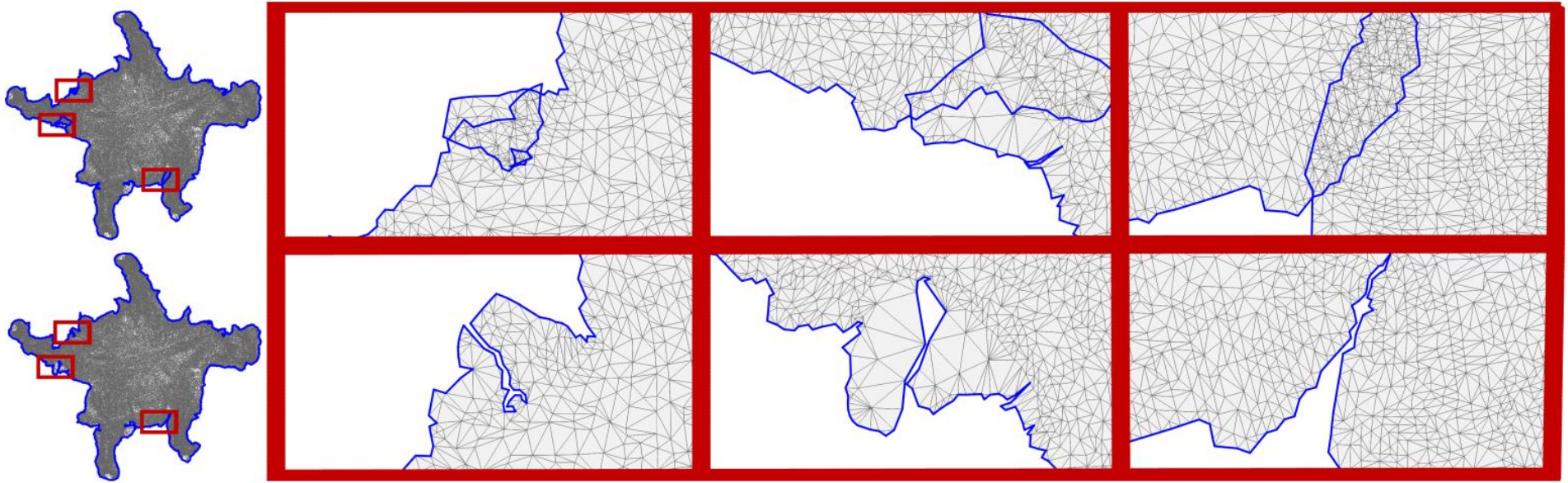
Seams introduce filtering artifacts

High-resolution texture



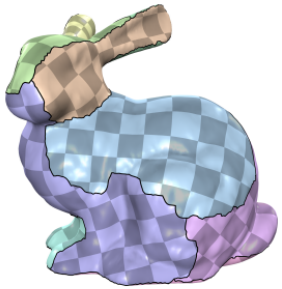
Parameterizations

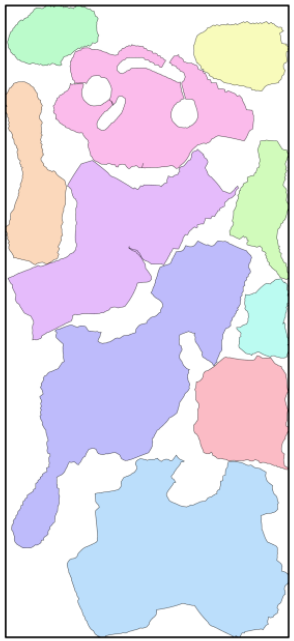
- Bijective
- Low isometric distortion



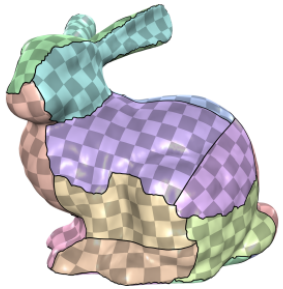
Packing

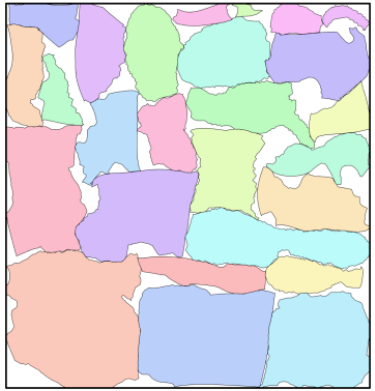
- High packing efficiency





PE = 66.0%
BL = 16.30
CN = 10

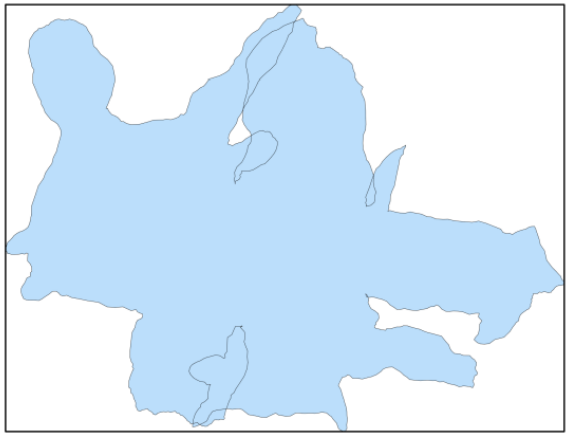


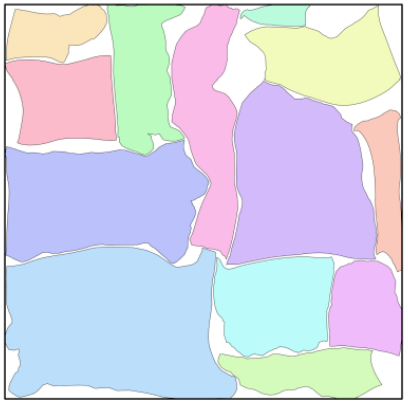


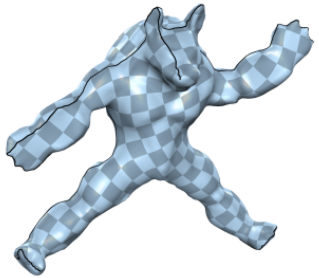
PE = 85.8%
BL = 21.24
CN = 26

Packing

- High packing efficiency







BL = 6.34
E_d = 1.040

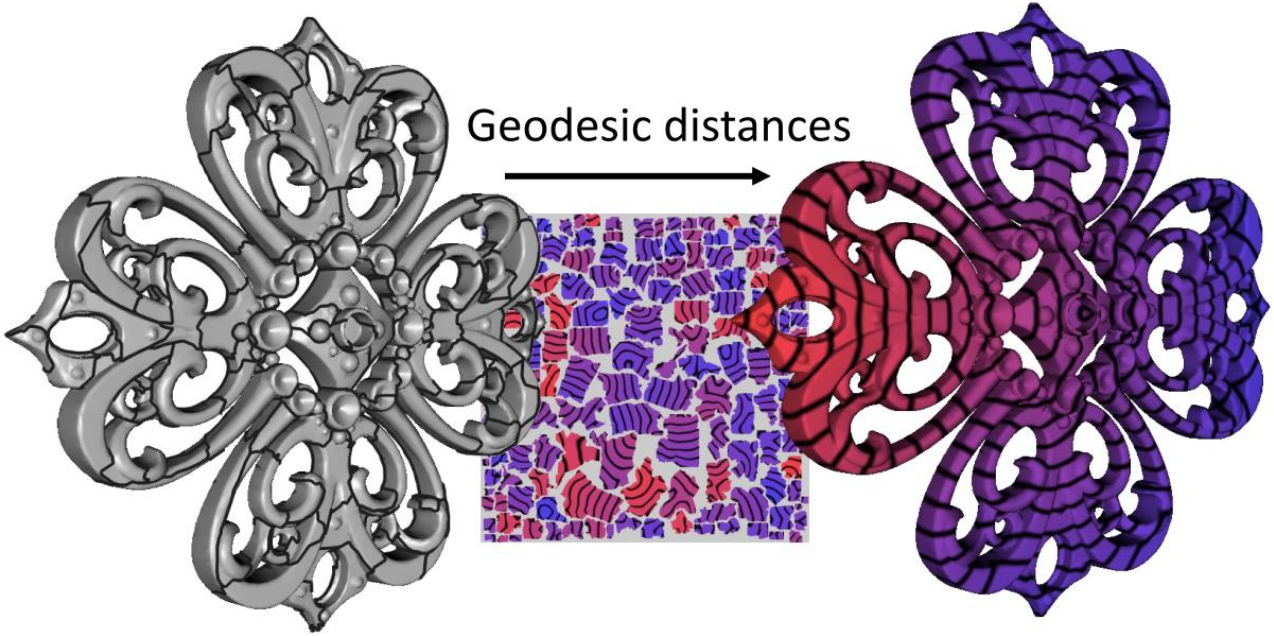
Input

PE = 85.0%
BL = 11.45
CN = 13
E_d = 1.030

Result

Applications

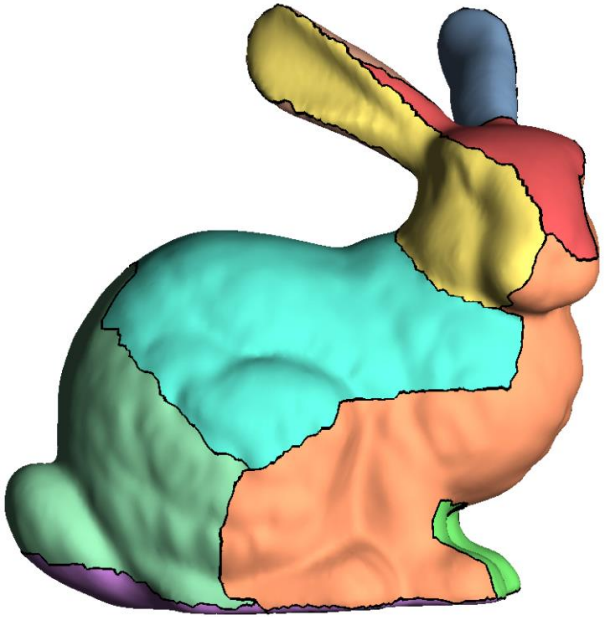
- Signal storage
- Geometric processing



Gradient-Domain Processing within a Texture Atlas

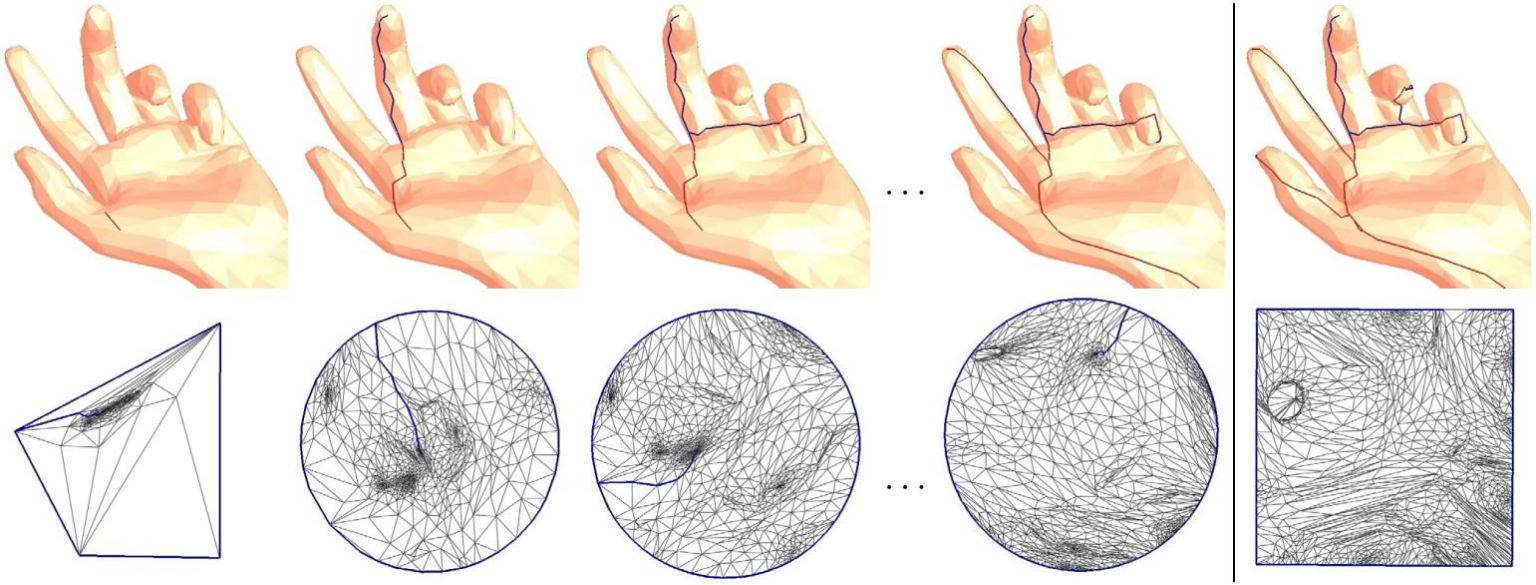
Mesh cutting

- Points → Paths
- Segmentation



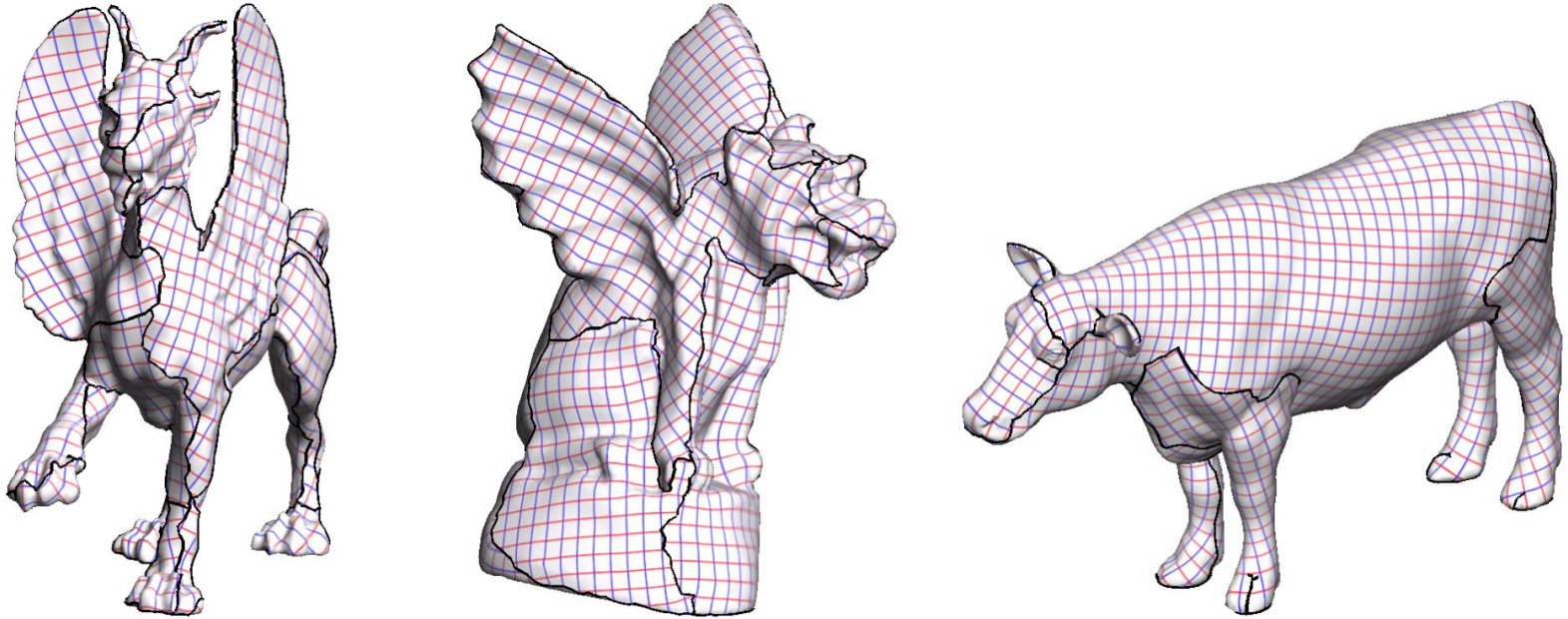
Distortion points

- Iterative method
  - Parameterize the mesh to the plane.
  - Add the point of greatest isometric distortion.



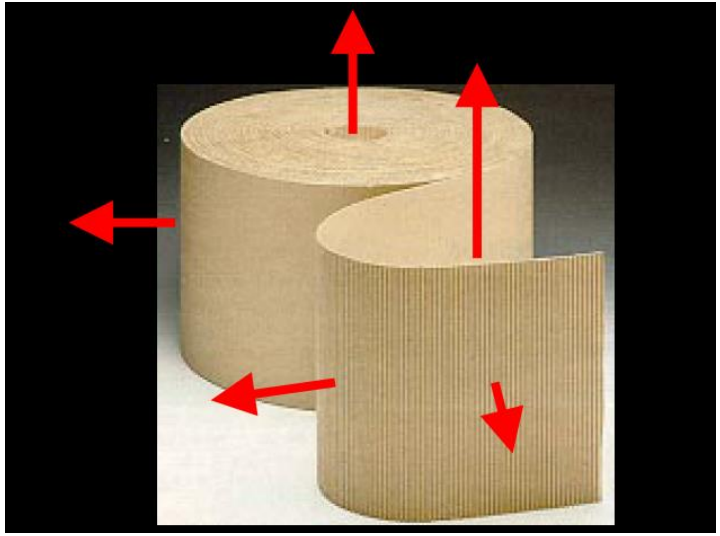
Segmentation

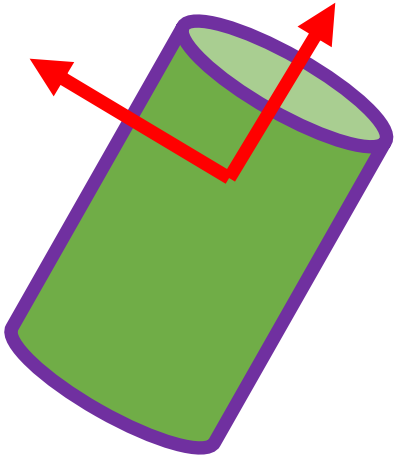
- Goal: mesh segmentation into compact charts that unfold with minimal distortion



Proxy

- Devlopable surfaces of constant slope
- Constant angle between surface normal and axis
- Proxy: $< axis, angle >, < N_c, \theta_c >$





Fitting error

- Measures how well triangle fits a chart

$$F(C,t) = (N_c \cdot n_t - cos\theta_c)^2$$

- Combine with compactness

$$C(C,t) = \frac{\pi D(S_c,t)^2}{A_c}$$

✓ S_c is the seed triangle of the given chart

✓ $D(S_c,t)$ is the length of the shortest path (inside the chart) between the two triangles

✓ A_c is the area of chart C

- Cost function

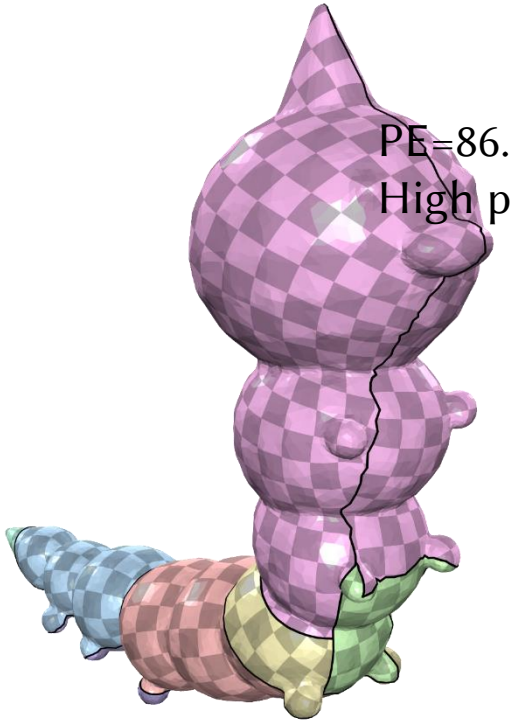
$$Cost(C,t) = A_t F(C,t)^{\alpha} C(C,t)^{\beta}$$

Segmentation method

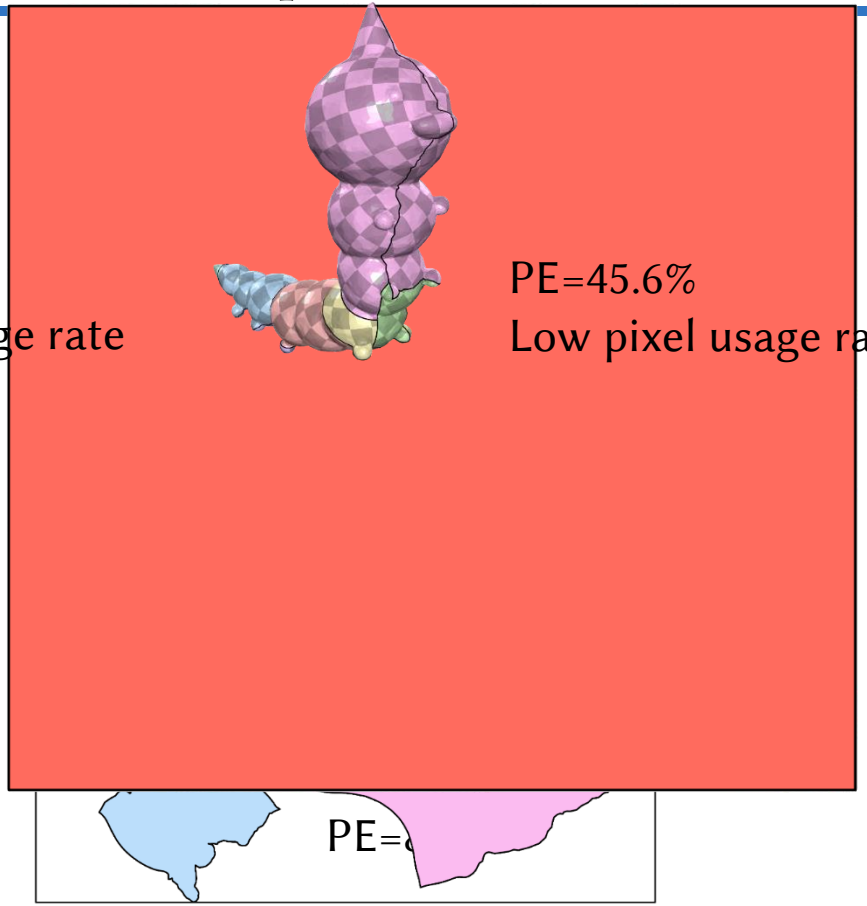
- Lloyd algorithm
  - 1. Select random triangles to act as seeds
  - 2. Grow charts around seeds using a greedy approach
  - 3. Find new proxy for each chart
  - 4. Repeat from step 2 until convergence
- K-means
- CVT

Packing

Packing efficiency (PE)



PE=86.1%
High pixel usage rate



PE=45.6%
Low pixel usage rate

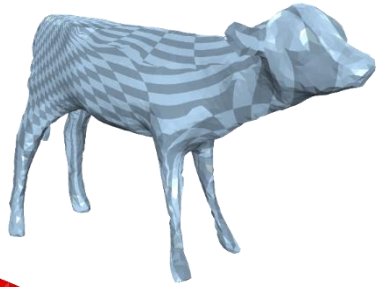
Packing efficiency (PE)

Maximizing atlas packing efficiency is NP-hard!

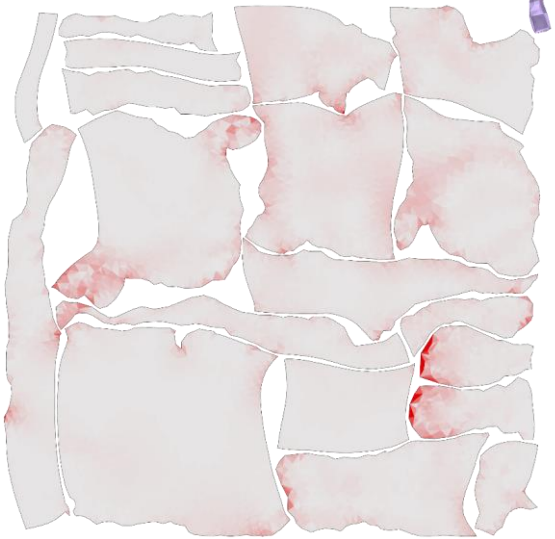
[Garey and Johnson 1979; Milenkovic 1999]

Other requirements

- Low distortion



High Distortion



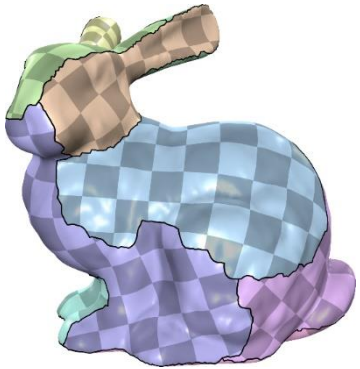
Low Distortion

Other requirements

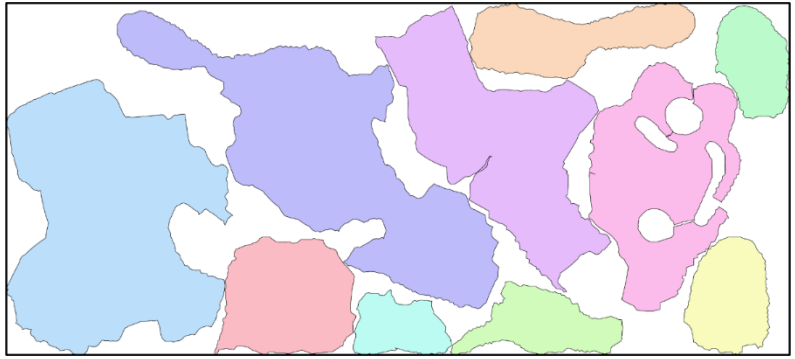
- Low distortion
  - [Golla et al. 2018; Liu et al. 2018; Shtengel et al. 2017; Zhu et al. 2018]
- Consistent orientation
  - [Floater 2003; Tutte 1963; Claici et al. 2017; Hormann and Greiner 2000; Rabinovich et al. 2017; Schüller et al. 2013]
- Overlap free
  - [Jiang et al. 2017; Smith and Schaefer 2015]
- Low boundary length
  - [Li et al. 2018; Poranne et al. 2017; Sorkine et al. 2002]

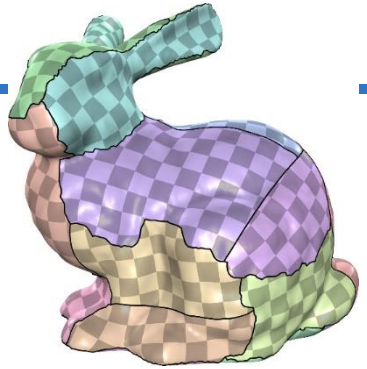
These methods do not consider PE!

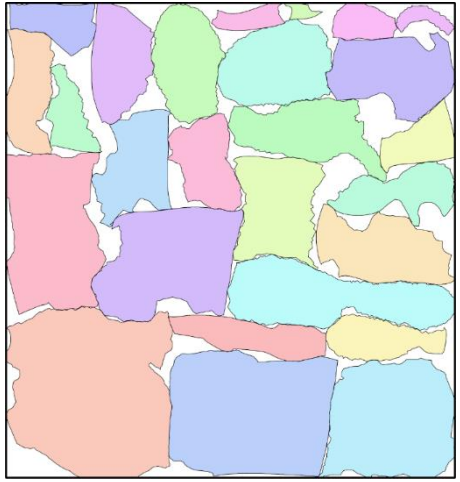
Atlas refinement



Input



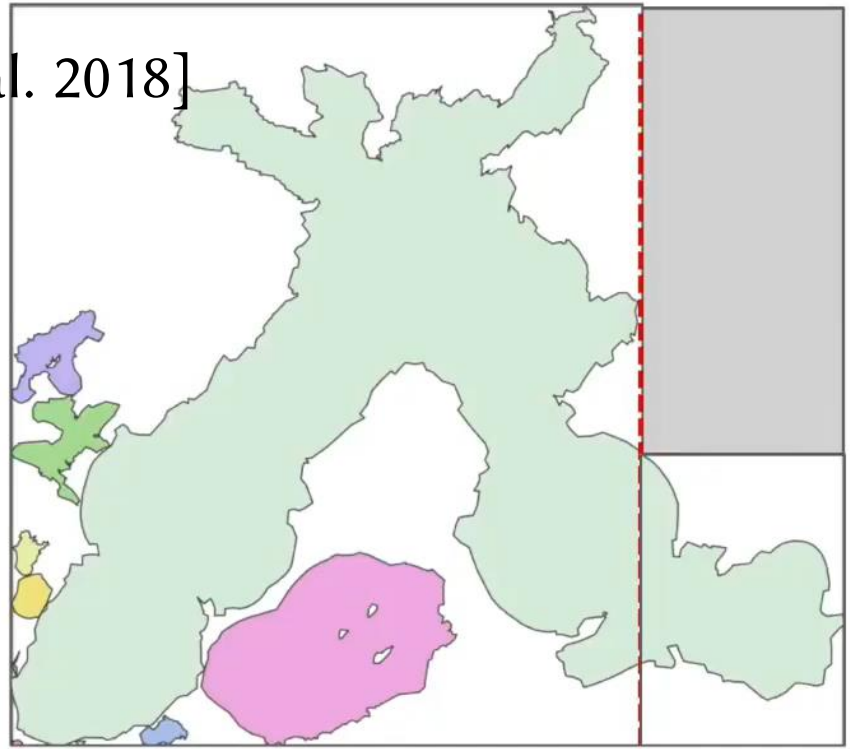




No overlap
High PE

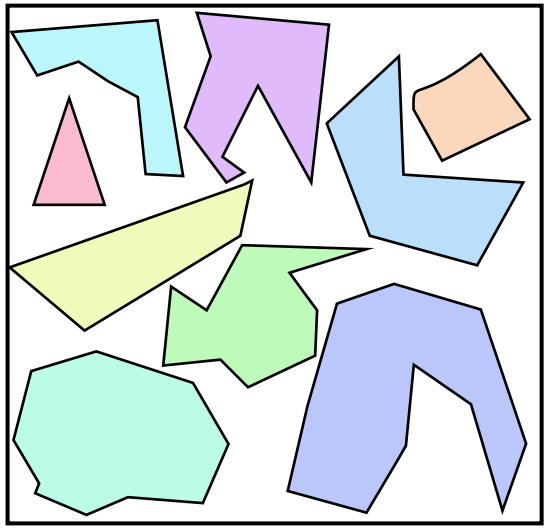
Previous work

Box Cutter [Limper et al. 2018]

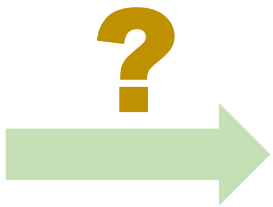


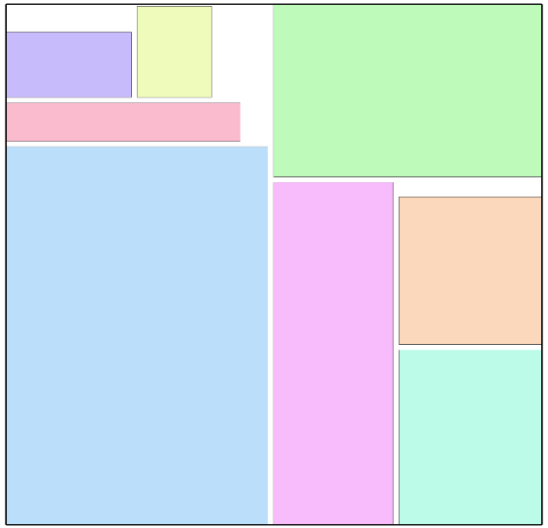
No guarantee for a high PE result!

Packing problems



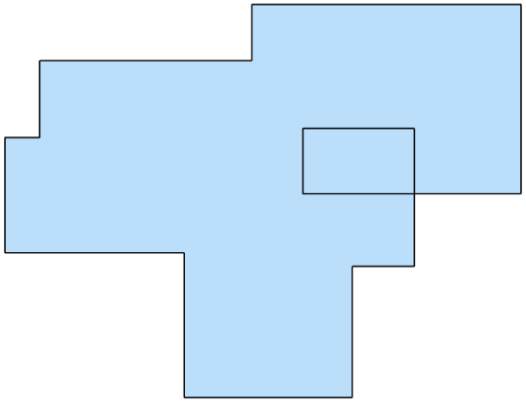
Irregular shapes
Hard to achieve high PE



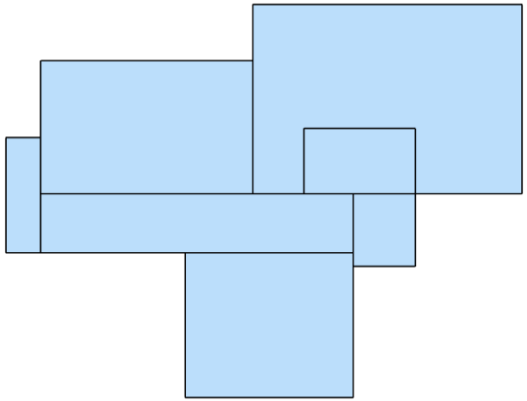


Rectangles
Simple to achieve high PE
Widely used in practice

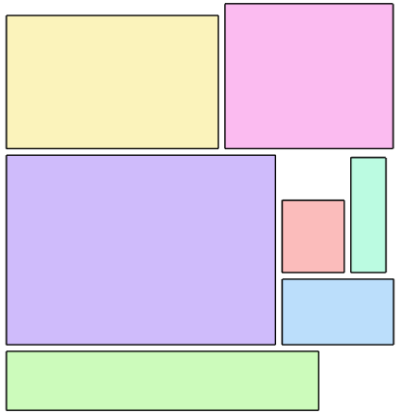
Axis-aligned structure



Axis-aligned structure

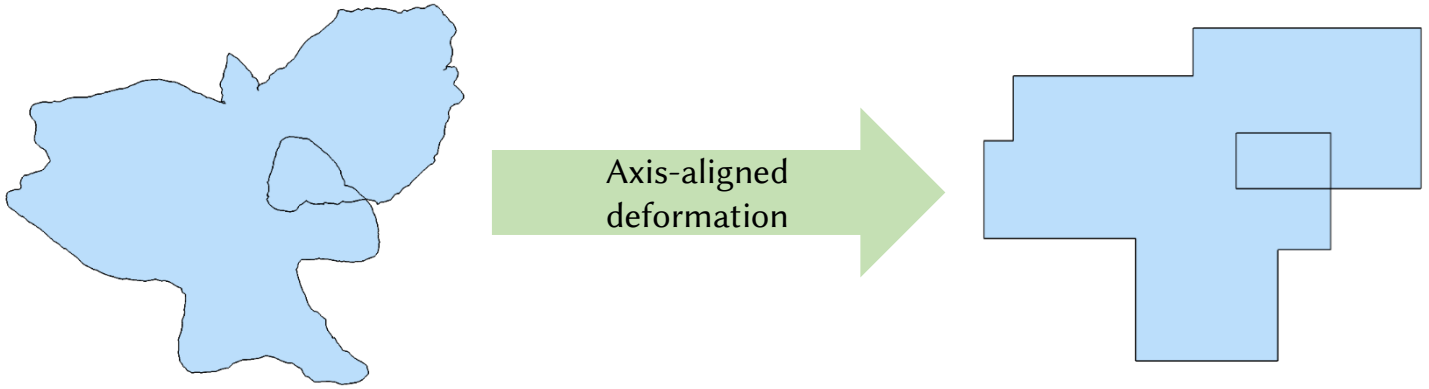


Rectangle decomposition



High PE (87.6%)!

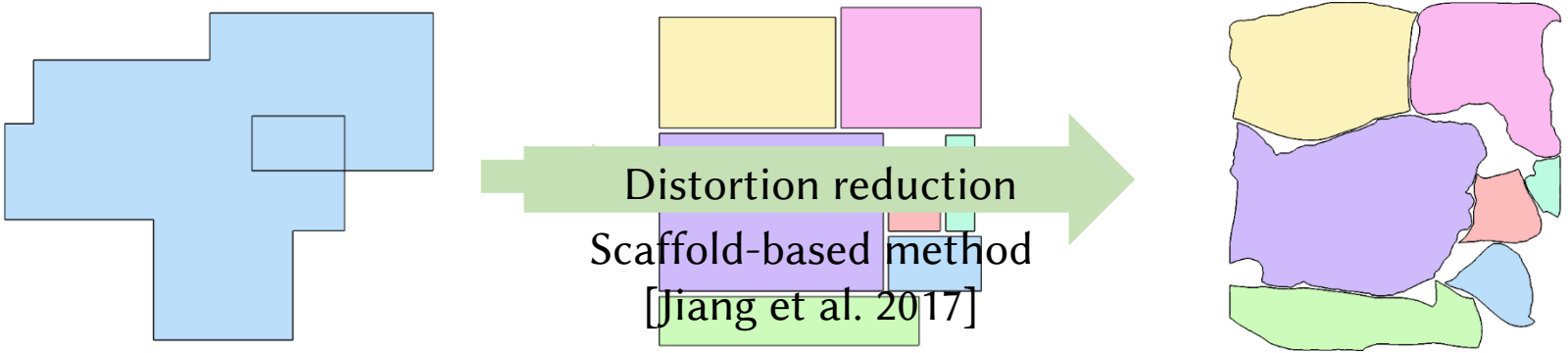
General Cases



Not axis-aligned

Axis-aligned
Higher distortion

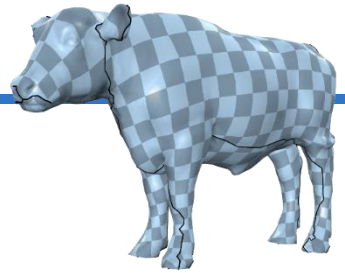
Distortion Reduction

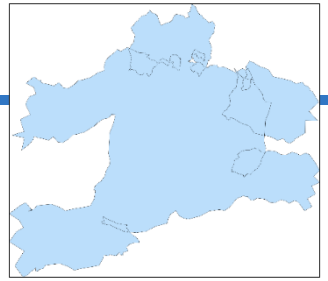


Axis-aligned
High distortion

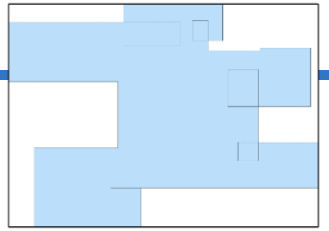
No overlap & High PE
High distortion

No overlap & High PE
Low distortion
Bounded PE



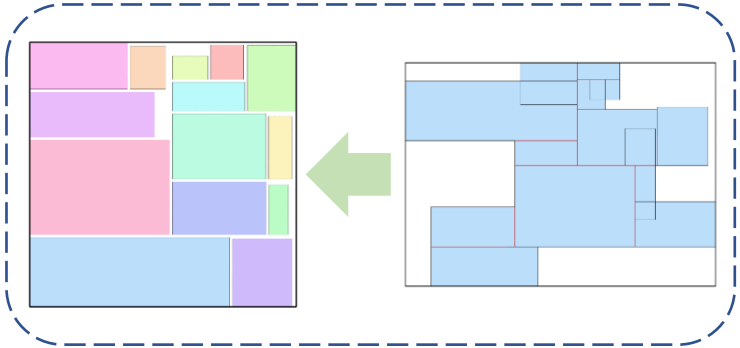


Axis-aligned deformation

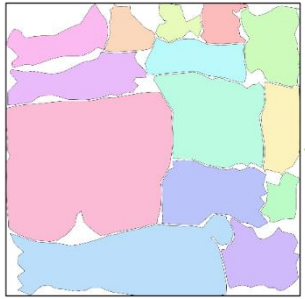


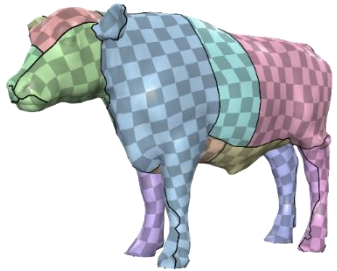
Rectangle decomposition and packing

Pipeline



Distortion reduction





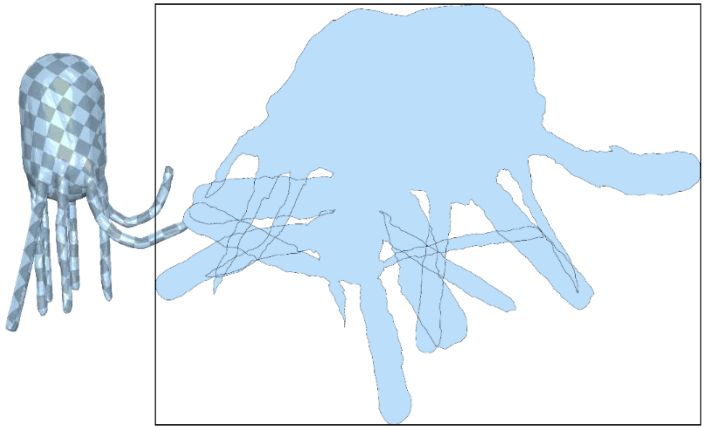
PolyAtlas: Atlas Refinement with Bounded Packing Efficiency

Submitted to ACM SIGGRAPH 2019

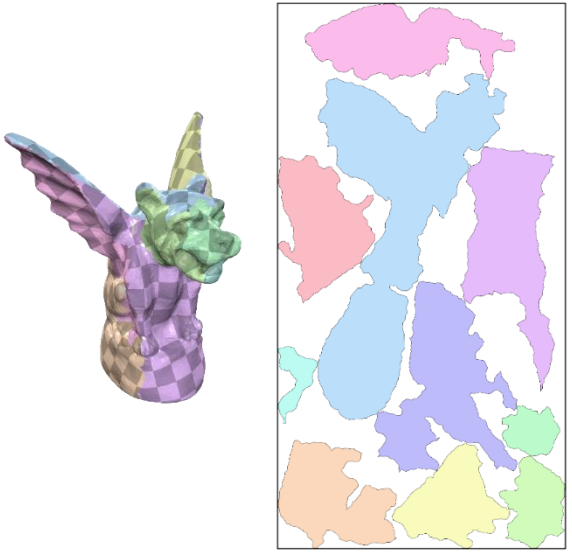
ID: 339

Axis-Aligned Deformation

- Input

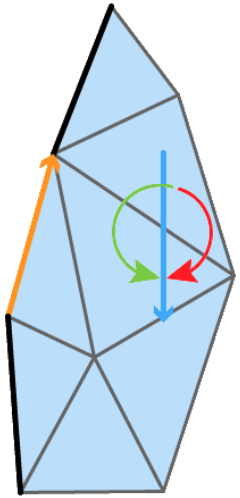


Single chart
With overlap



10 charts
Without overlap

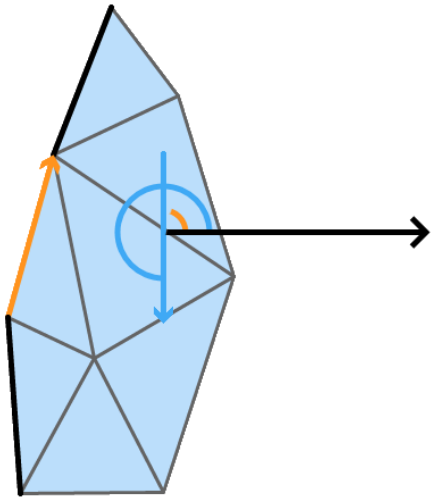
Axis-Aligned Deformation



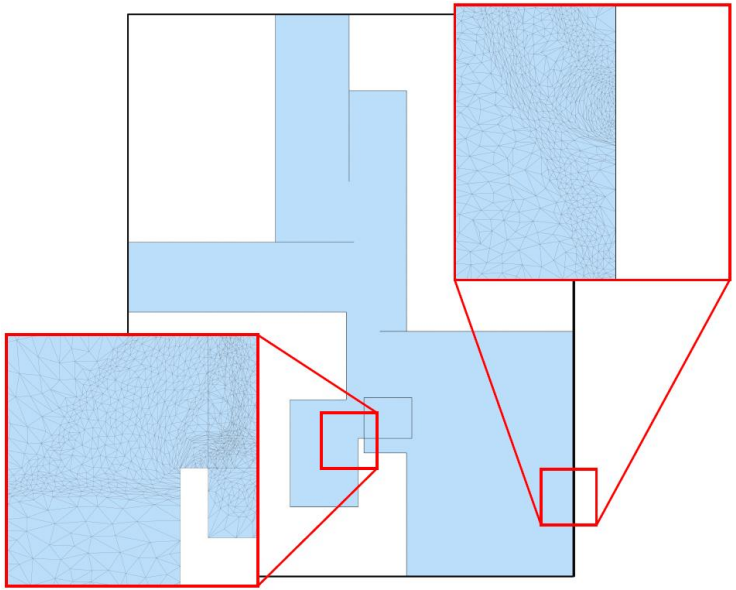
Direction vector
Ambiguous rotating directions

Fail!

Axis-Aligned Deformation

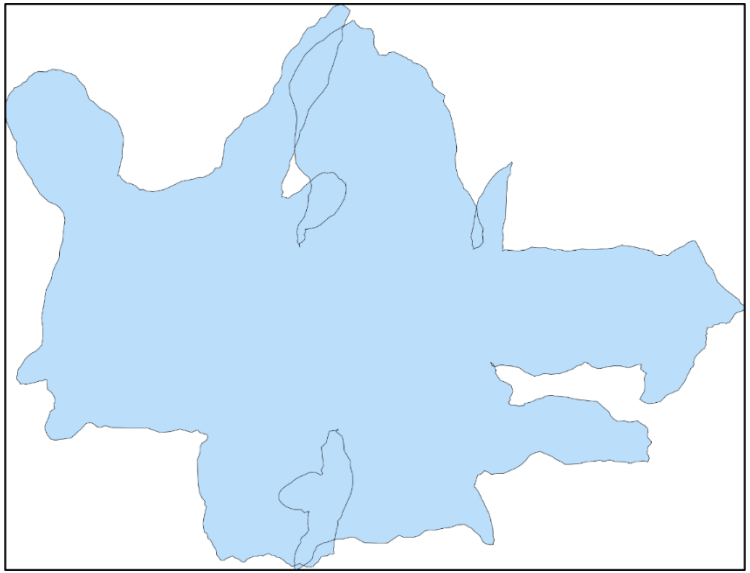


Polar angle
Clear rotating direction

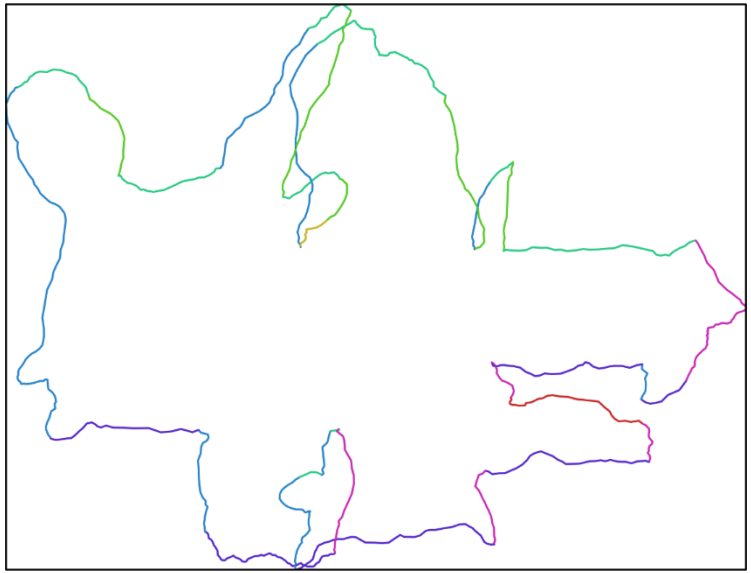


Success!

Axis-Aligned Deformation



Input



Target polar angle

Axis-Aligned Deformation

- Energy of boundary alignment

Rotate polar angle

Keep length

$$E_{\text{edge}}(\mathbf{b}_i) = \frac{1}{2}(1-\gamma)\left(\theta_i - \frac{\pi}{2}\Theta_i\right)^2 + \frac{1}{2}\gamma\left(\frac{l_i}{l_i^0} - 1\right)^2$$

$$E_{\text{align}}(\mathbf{c}) = \sum_{i=1}^{N_b} \frac{l_i^0}{l^0} E_{\text{edge}}(\mathbf{b}_i)$$

Axis-Aligned Deformation

- Energy of isometric distortion(symmetric Dirichlet)

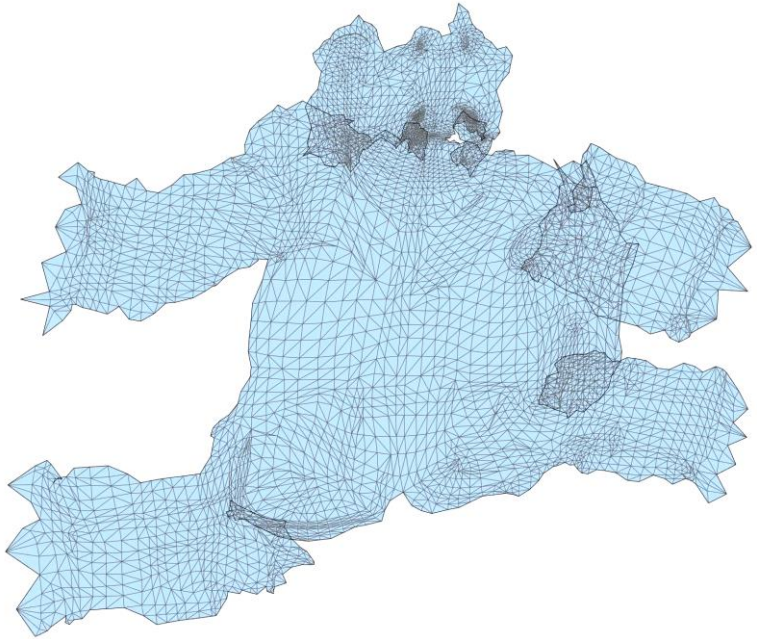
$$E_{\mathrm{d}}(\mathrm{c}) = \frac{1}{4} \sum_{\mathrm{f_i} \in \mathrm{F^c}} \frac{\mathrm{Area}(\mathrm{f}_i)}{\mathrm{Area}(\mathrm{M^c})} \left(\|J_i\|_F^2 + \|J_i^{-1}\|_F^2 \right)$$

Keep low distortion and orientation consistency.

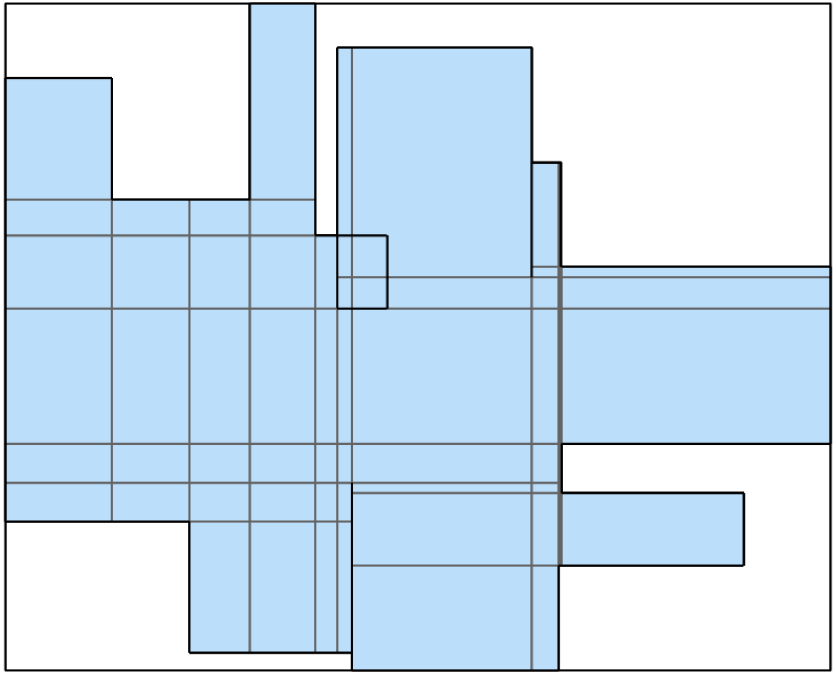
Axis-Aligned Deformation

$$\min_{\mathrm{c}} \quad E_{\mathrm{d}}(\mathrm{c}) + \lambda E_{\mathrm{align}}(\mathrm{c})$$
$$\text{s.t.} \quad \det J_i > 0, \forall i$$

0.2X Playback



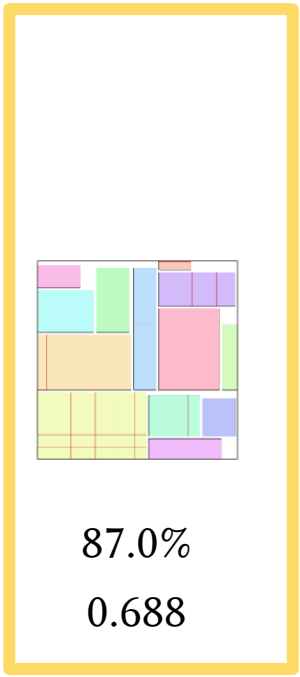
Rectangle Decomposition and Packing

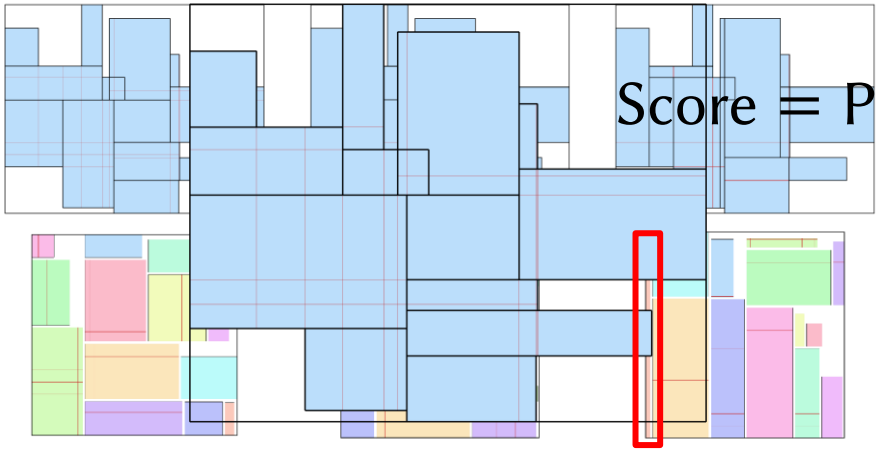


The faces are all rectangles.
But the number is too many.

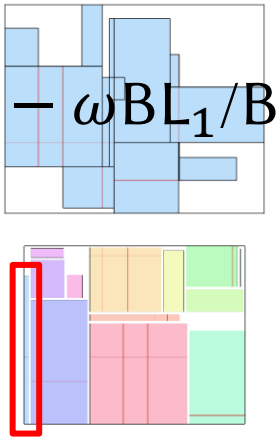
Rectangle Decomposition and Packing

- Motorcycle graph algorithm





$$\text{Score} = \text{PE} - \omega \text{BL}_1/\text{BL}_0$$



PE	87.0%	83.6%	84.4%
Score	0.688	0.659	0.658

Distortion Reduction

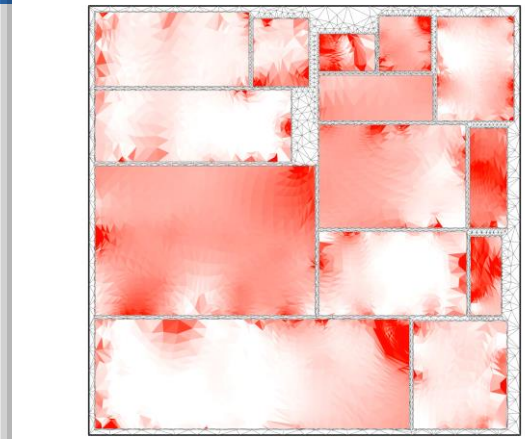
Isometric energy

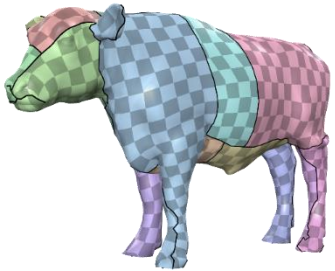
$$\min_{C} E_{\text{reduction}} = E_{\text{d}}(C) + E_{\text{PE}}(C)$$

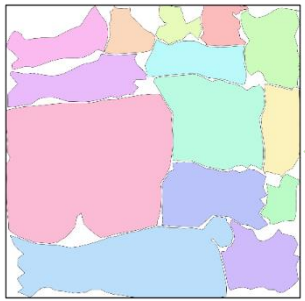
$$\text{s.t. } \Phi \text{ is bijective}$$

Barrier function of PE bound

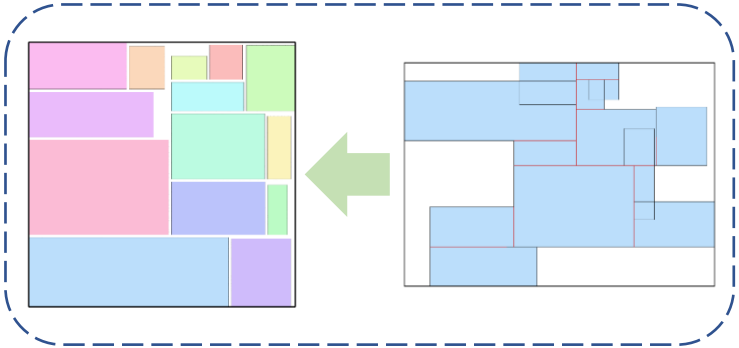
Scaffold-based method [Jiang et al. 2017]



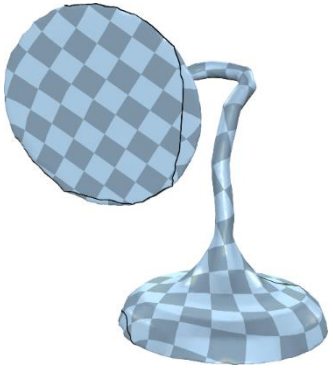


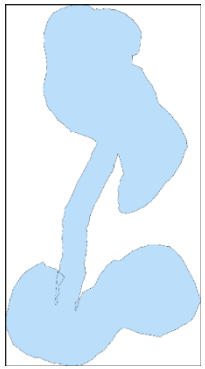


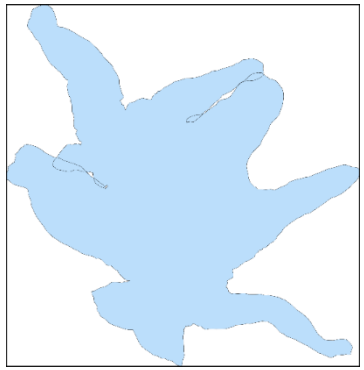
Distortion reduction



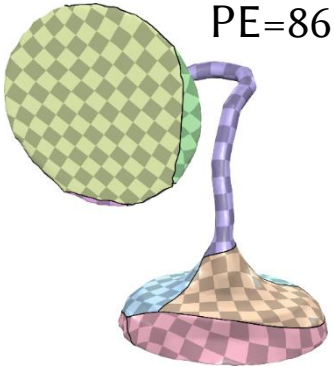
Benchmark (5,588)

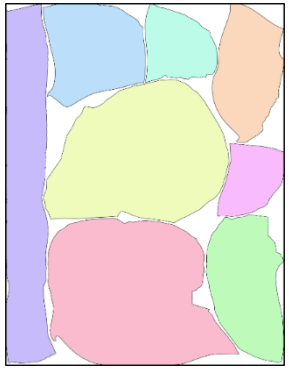




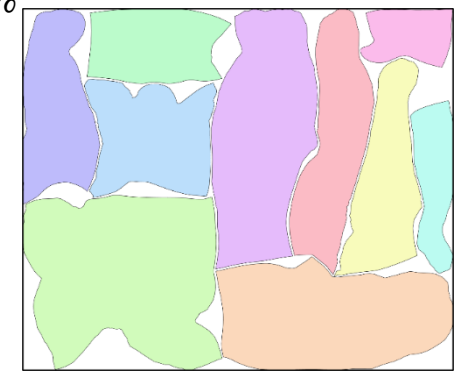


PE=86.2%

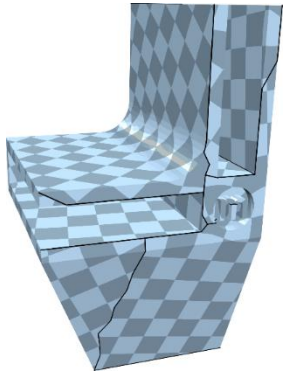


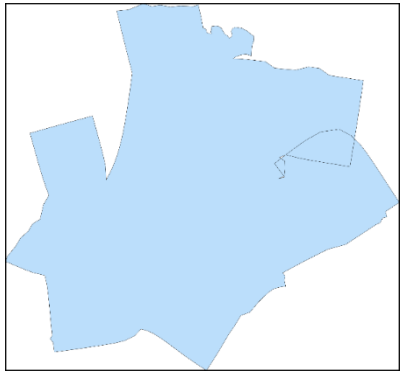


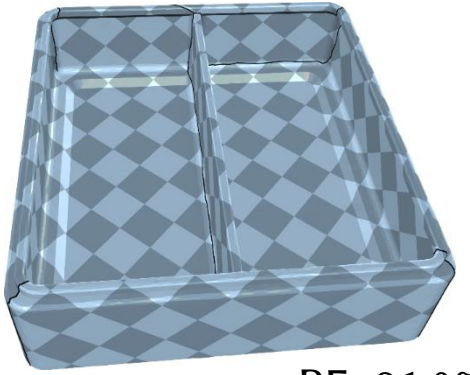
PE=86.7%



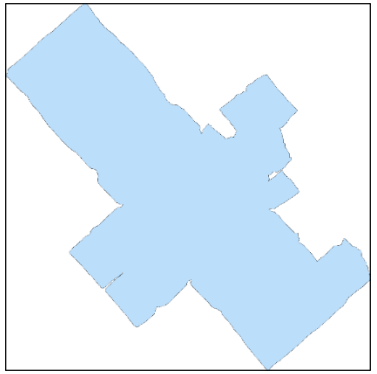
Benchmark (5,588)



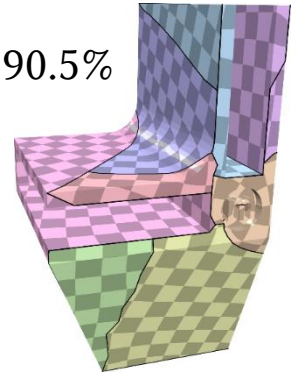


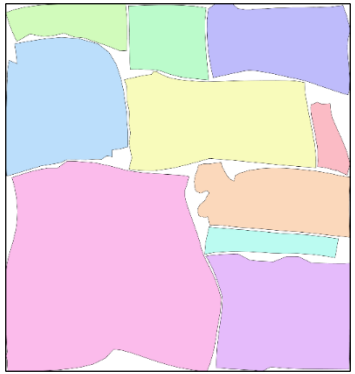


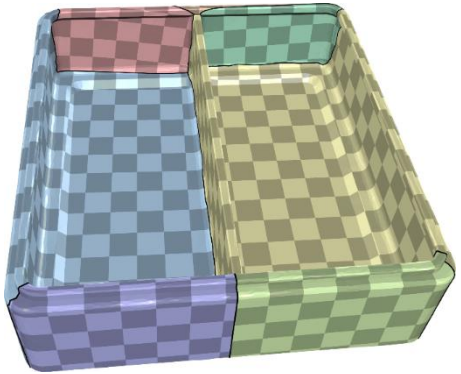
PE=91.0%

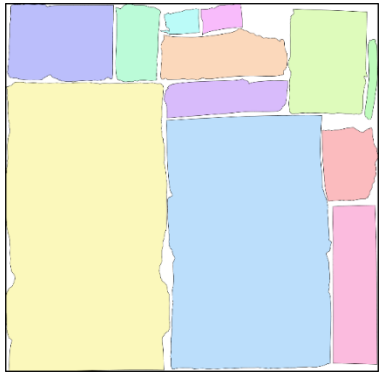


PE=90.5%









中国科学技术大学

University of Science and Technology of China

谢 谢 ！