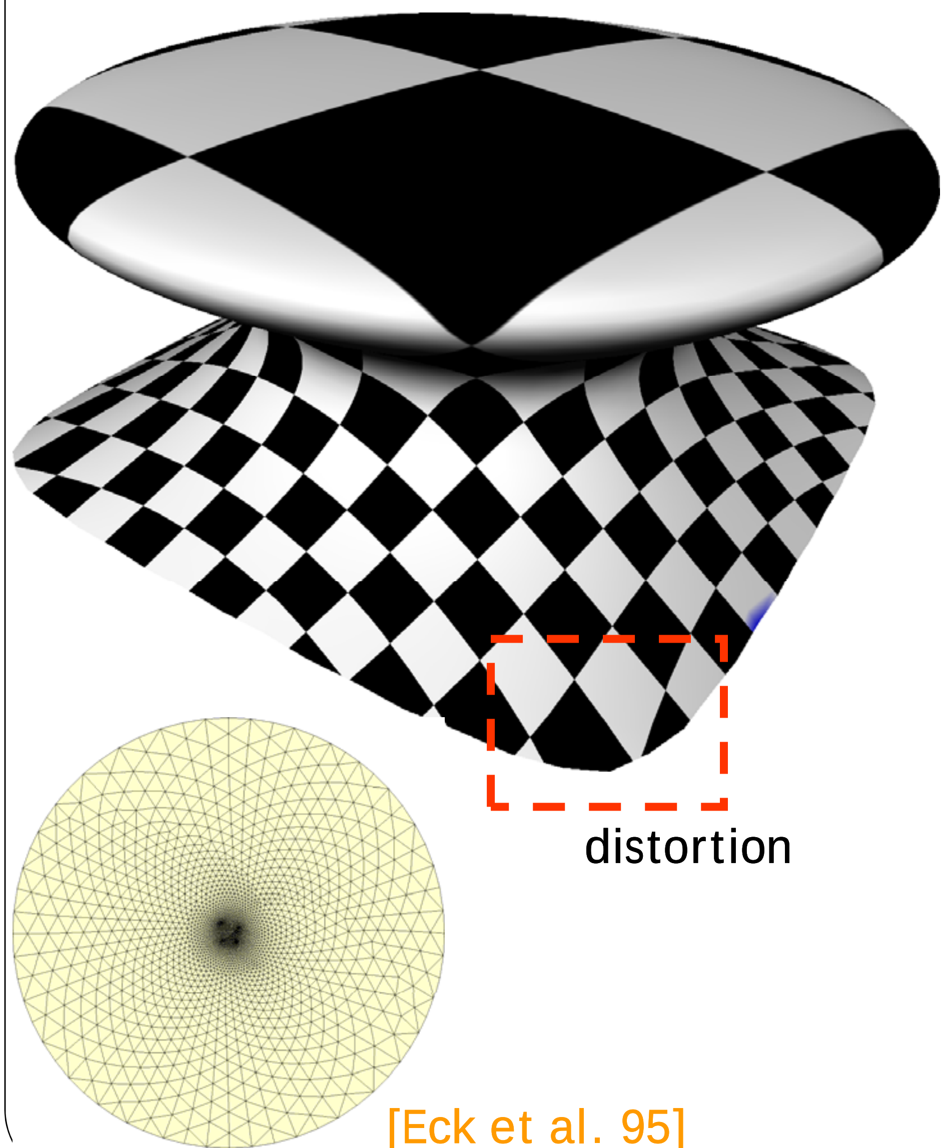
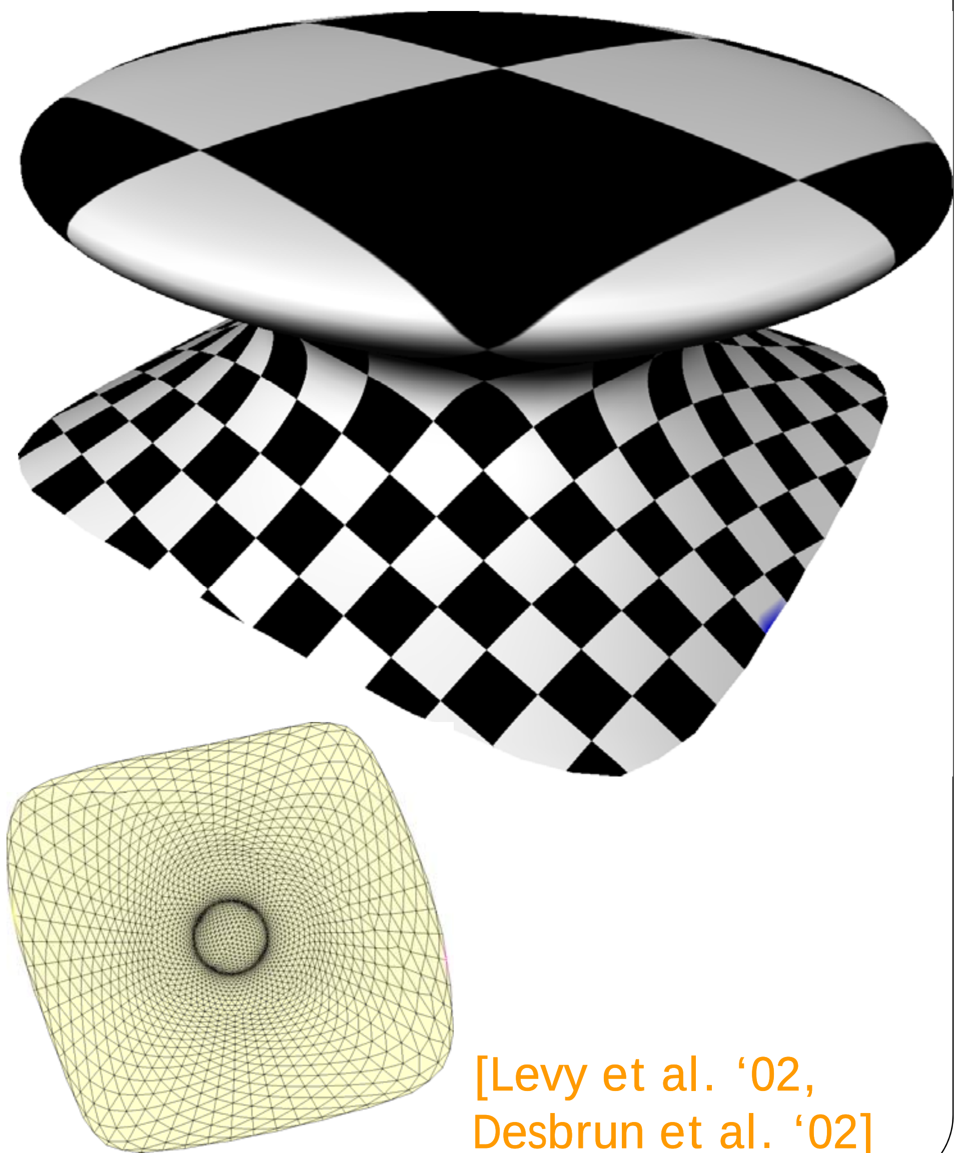
(Re)Meshing

Nov. 17, 19, 2009

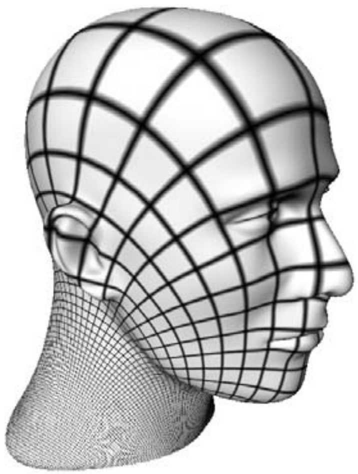
Conformal: fixed vs free boundary



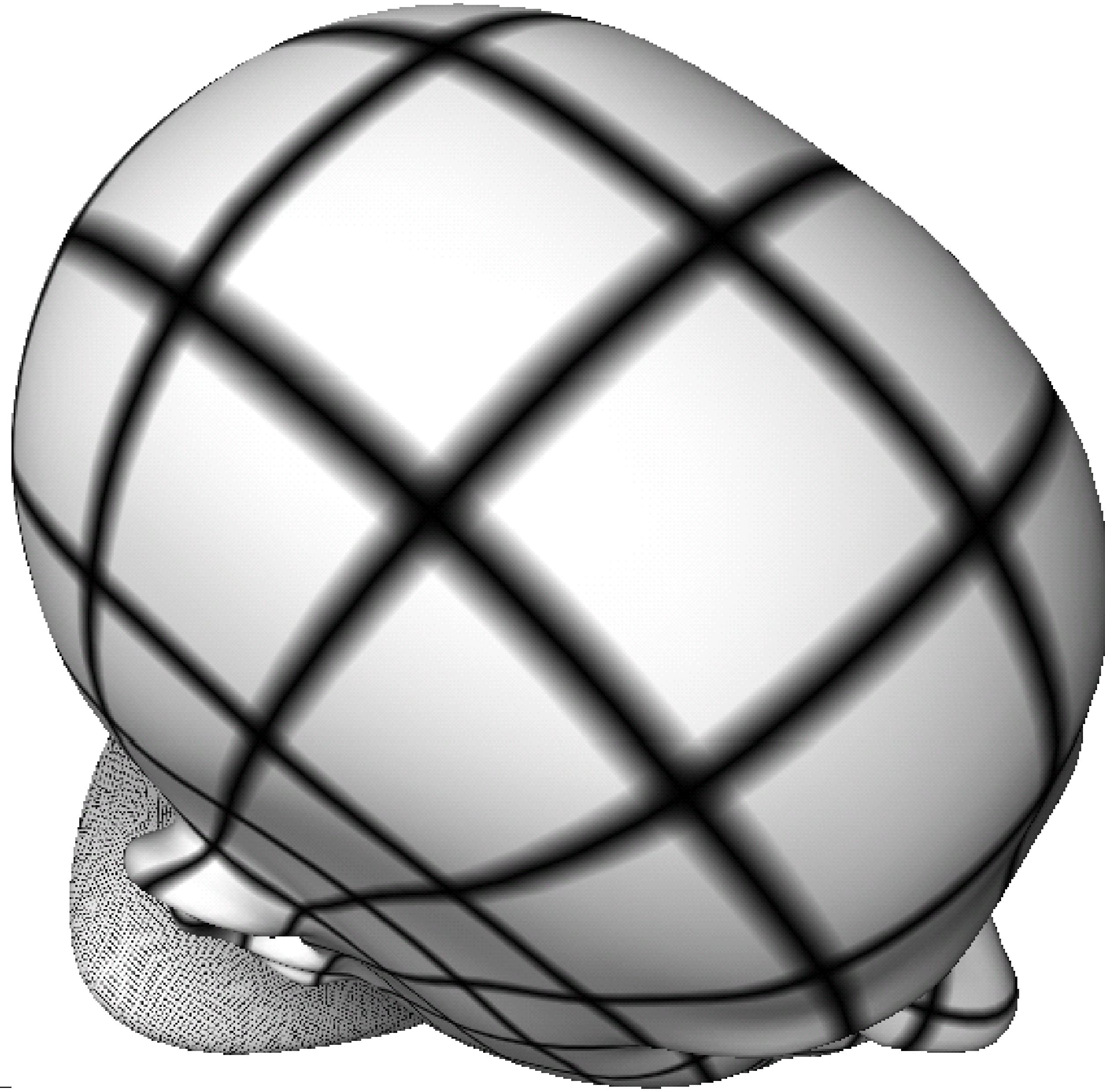
[Eck et al. 95]


[Levy et al. ‘02,
Desbrun et al. ‘02]

Preservation of angles

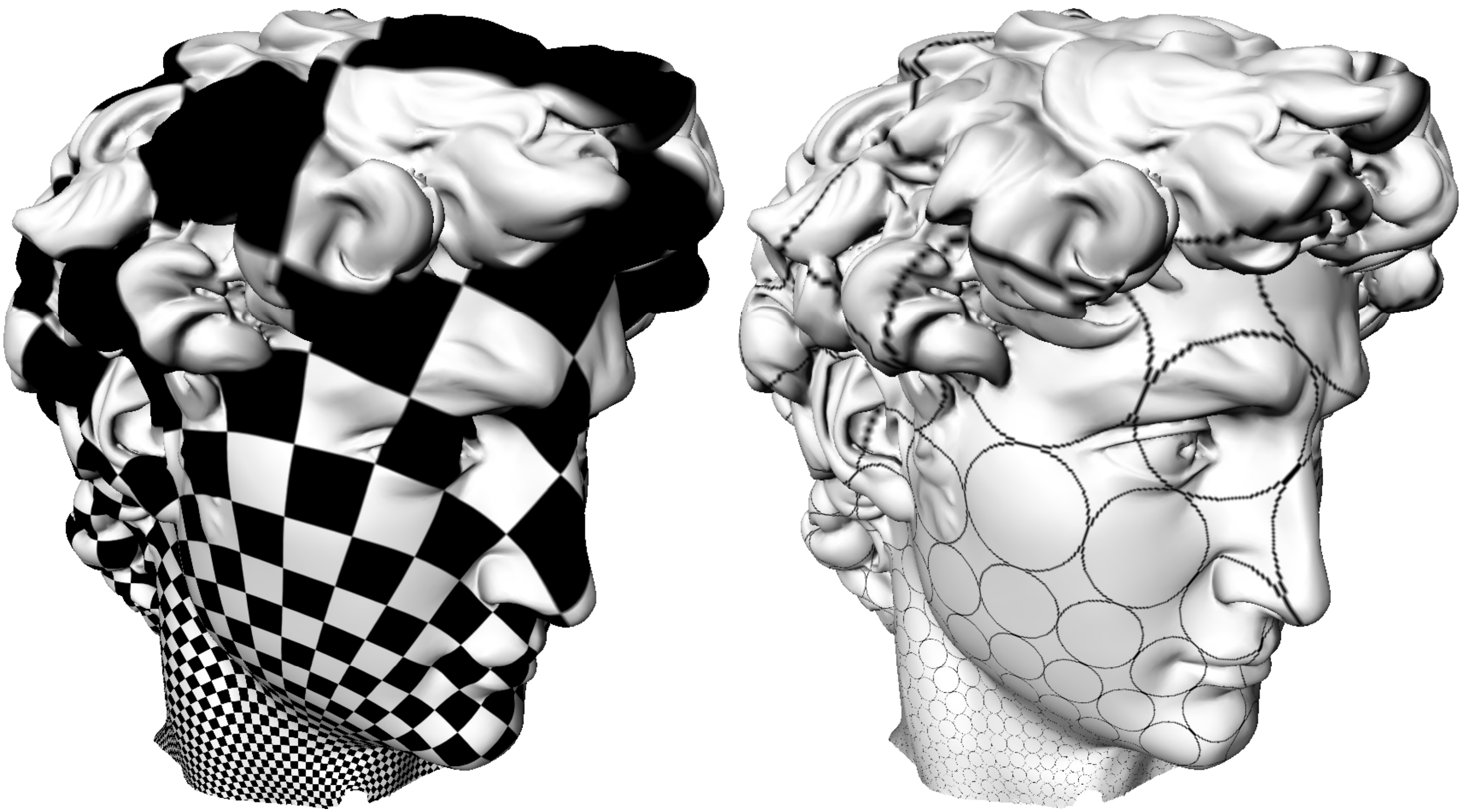


Isoparametric lines

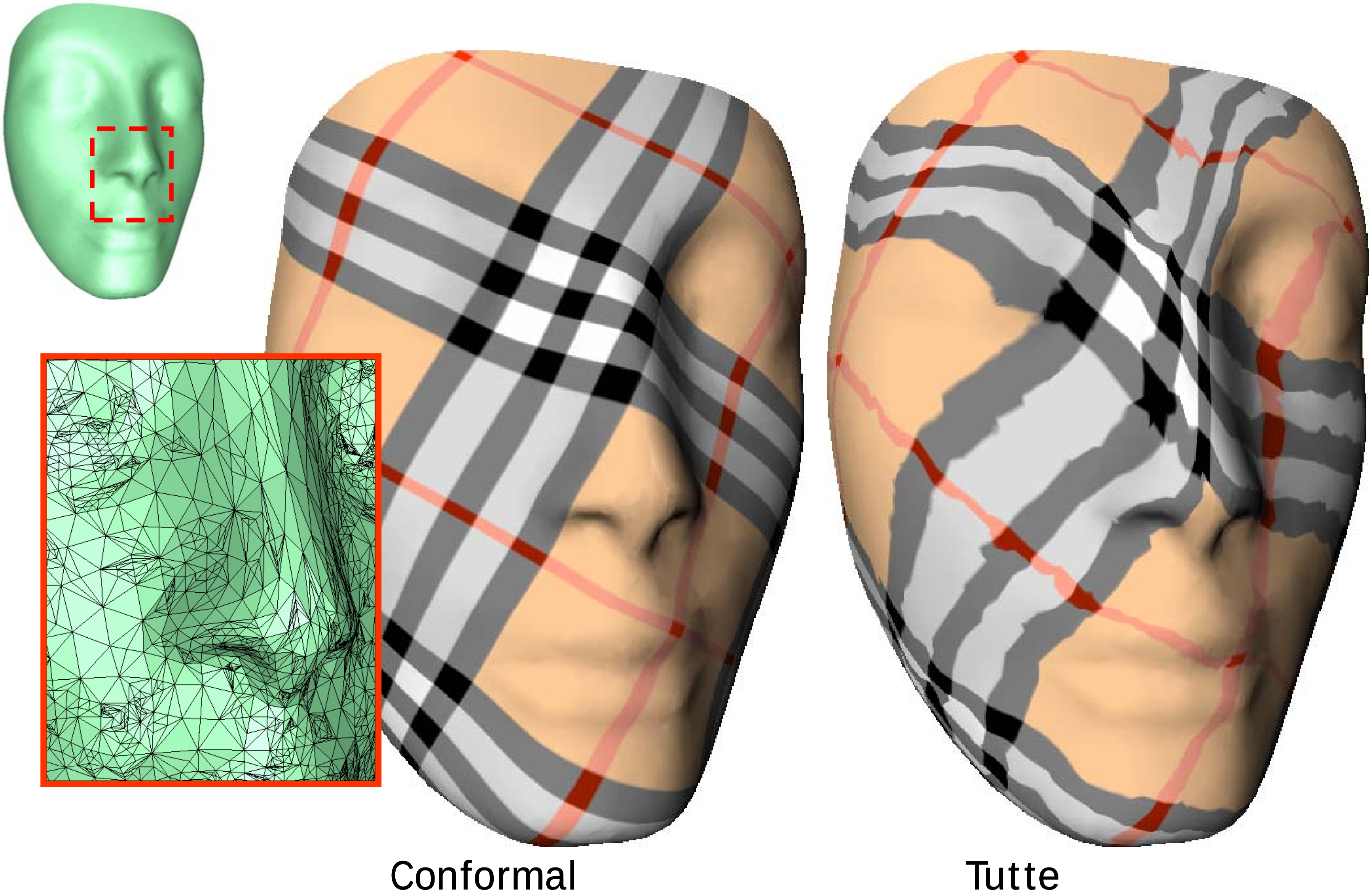


Conformality

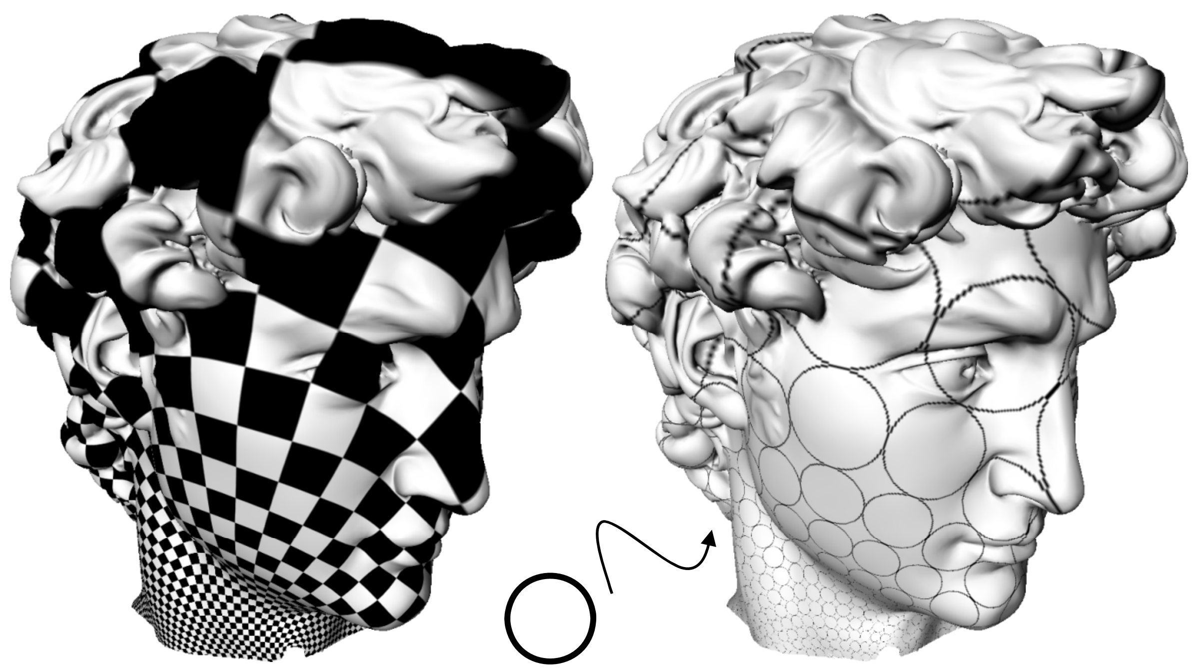
Angle-preserving + locally isotropic



Behavior w.r.t. sampling

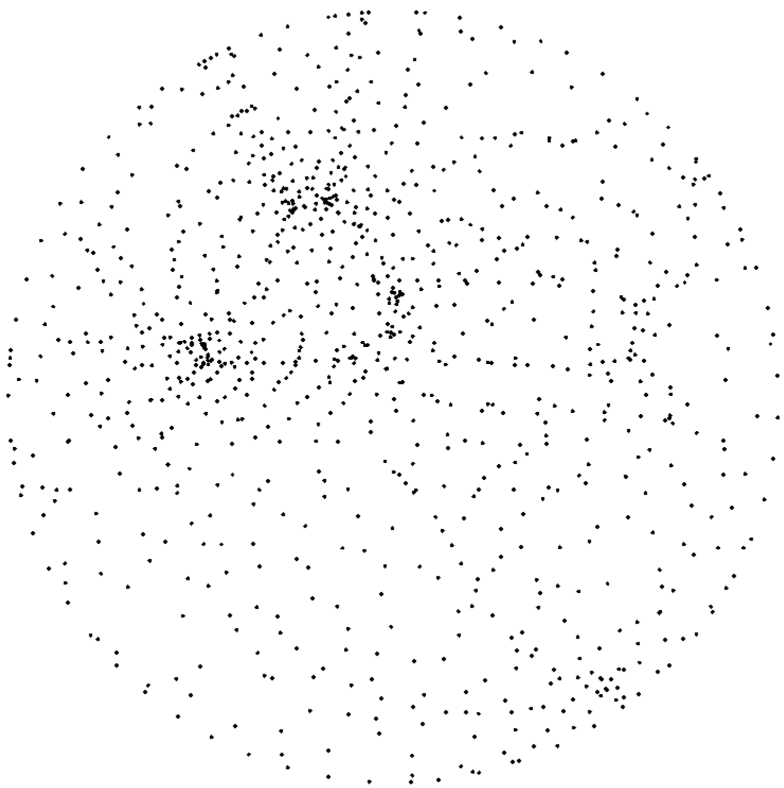


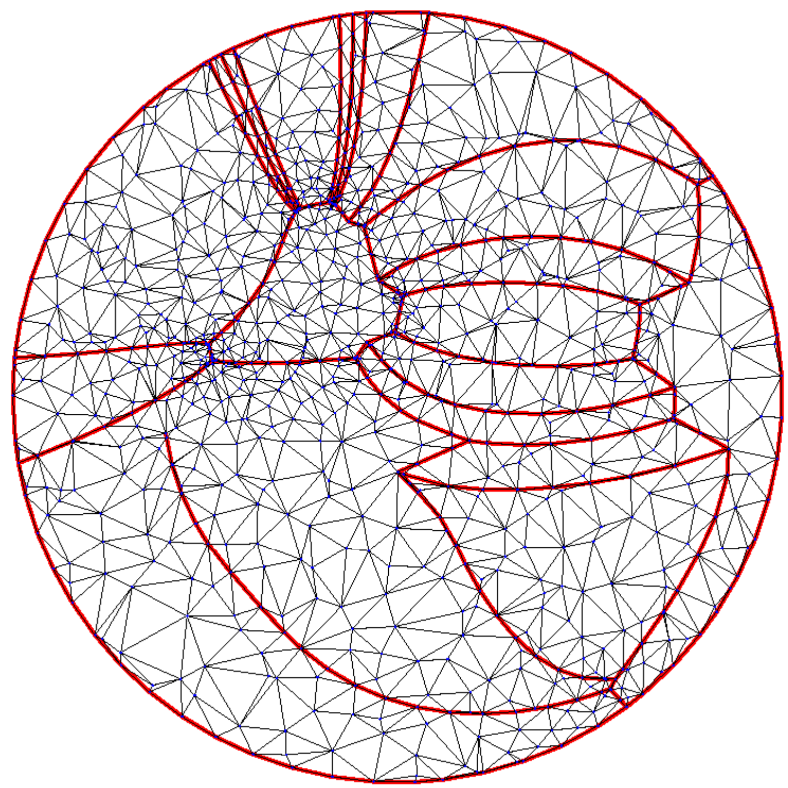
"A well-shaped element in parameter space will not be deformed too much once lifted in embedding space"



- Motivation
- Previous work
- Contributions
- Algorithm
  - sample repartition *error diffusion*
  - parameterization *conformal*
  - meshing
  - sample placement

Meshing





Constrained Delaunay triangulation
in parameter space
[CGAL] -> solves robustness issues

Motivation

Previous work

Contributions

Algorithm

– sample repartition *error diffusion*

– parameterization *conformal*

– meshing *Delaunay*

– sample placement

Sample placement

Given a bounded domain and a density function,

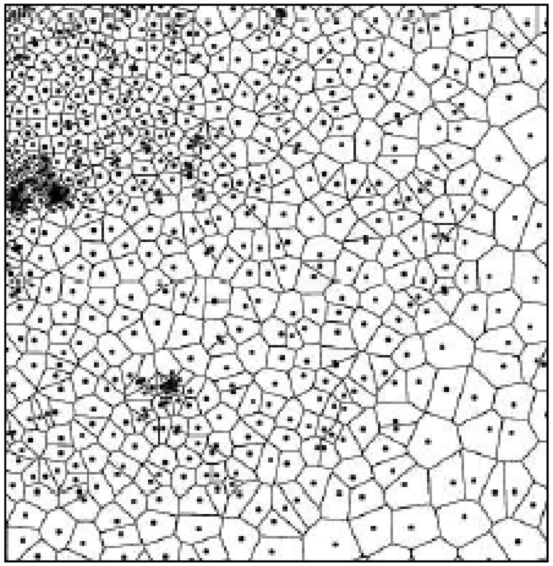
sampling

=

- partitioning the domain
- repartitioning the density function among a set of samples

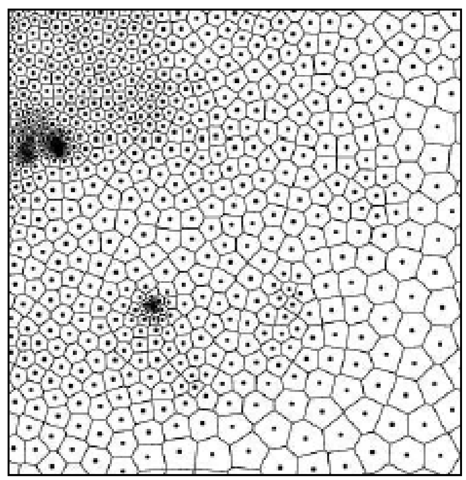
Sample placement

- partitioning the domain
  -> Voronoi tessellation
- repartitioning the density function among a set of samples
  = Equal-mass enclosing



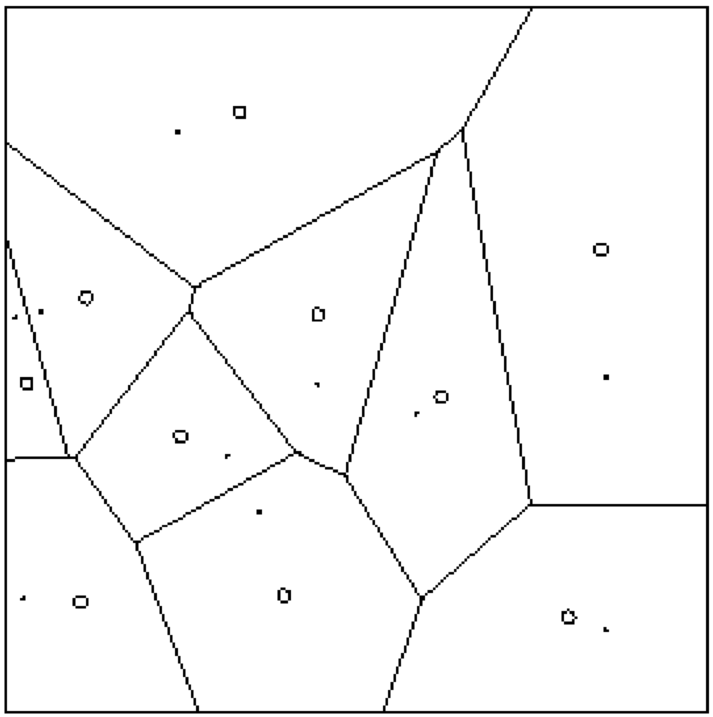
Isotropic sampling

- sampling
  - partitioning
  - equal-mass enclosing
- isotropic sampling
  - each tiles as compact as possible

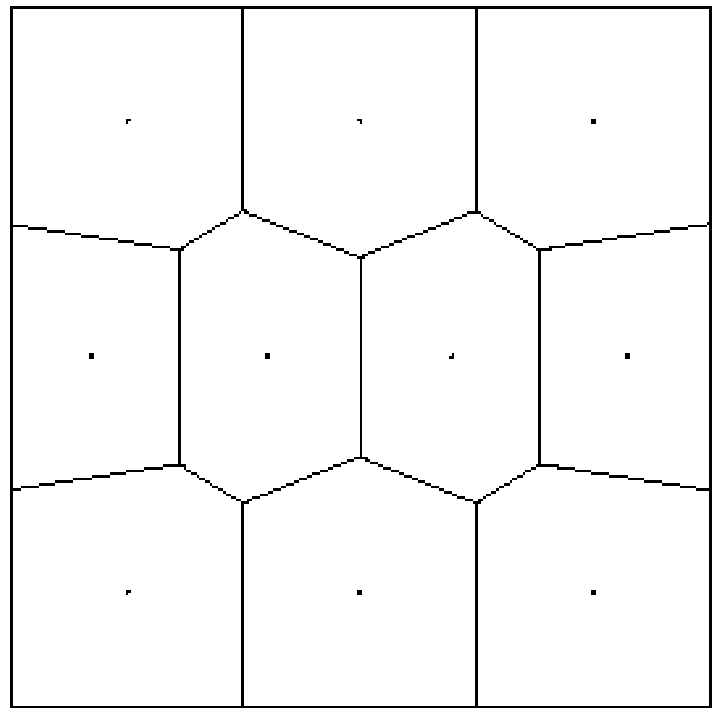


centroidal Voronoi tessellation satisfies both conditions

Centroidal Voronoi diagram



Ordinary Voronoi diagram

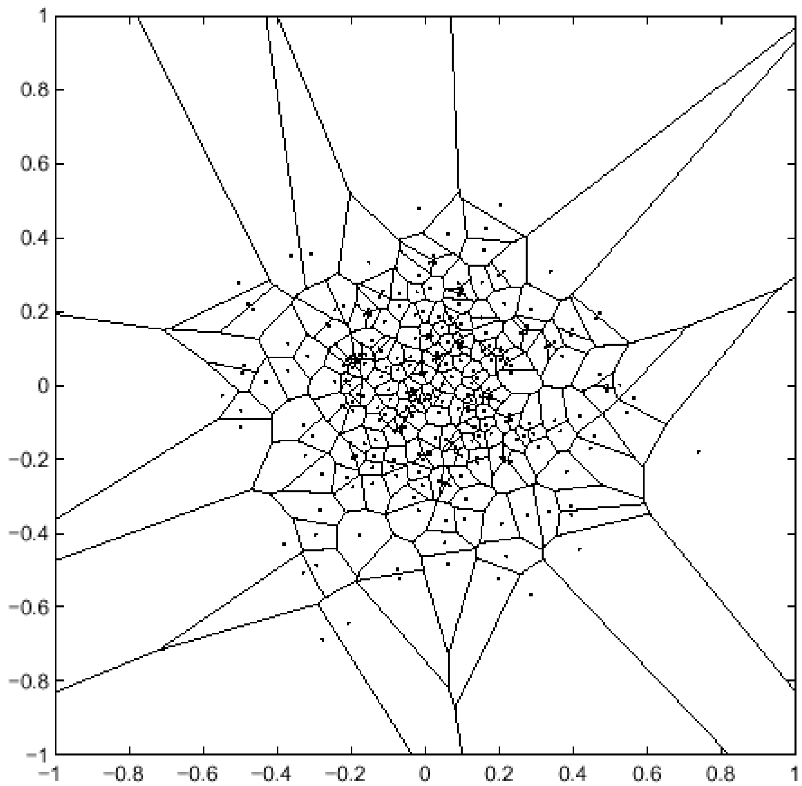


Centroidal Voronoi diagram

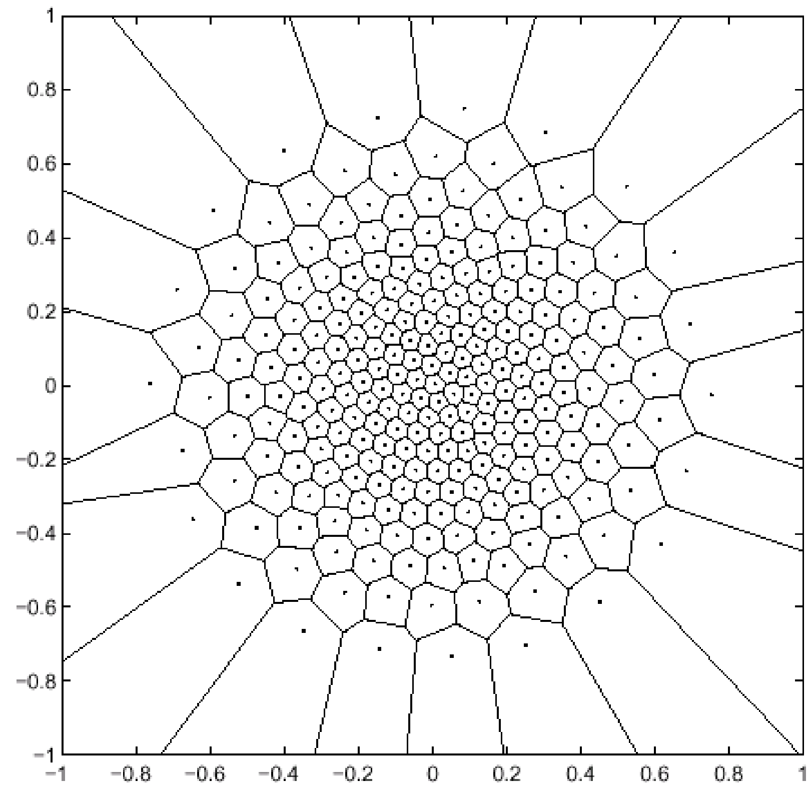
- ● sites
- ○ centroids

Sites coincide with centroids (center of mass)

Weighted Centroidal Voronoi diagram



Monte-Carlo



WCVD

Non-uniform density

Centroidal Voronoi diagram

Used for:

- optimal clustering
- optimal repartition of resources
- quantization
- tiling, etc. [Du *et al.* 01]

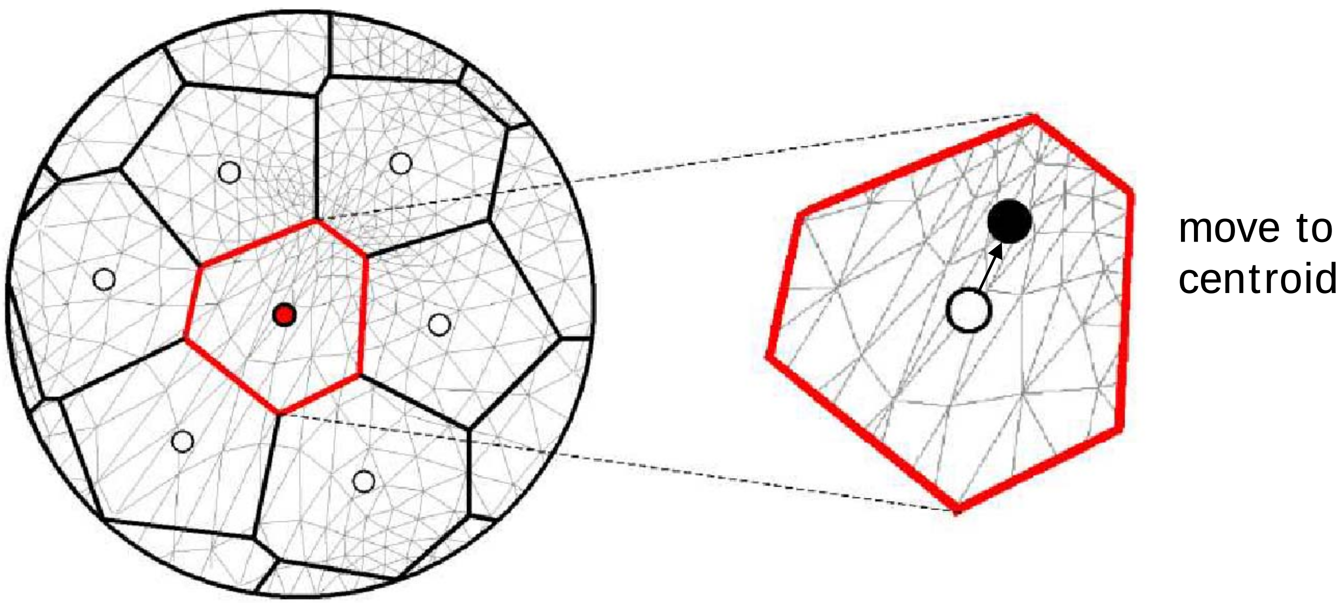
Note:

- special configuration, not algorithm
- several algorithms: Lloyd, k-means, etc.
- works in nD

Sample placement

Two process sorted by increasing degrees of freedom:

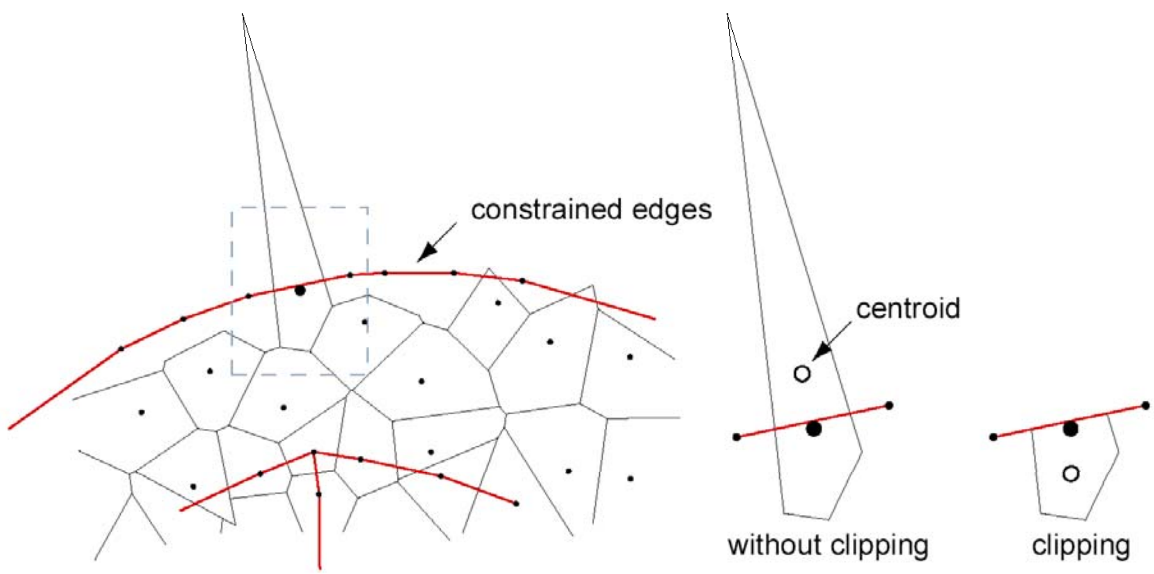
1. build 1D WCVD
2. build 2D WCVD via Lloyd relaxation



Asymmetric behavior

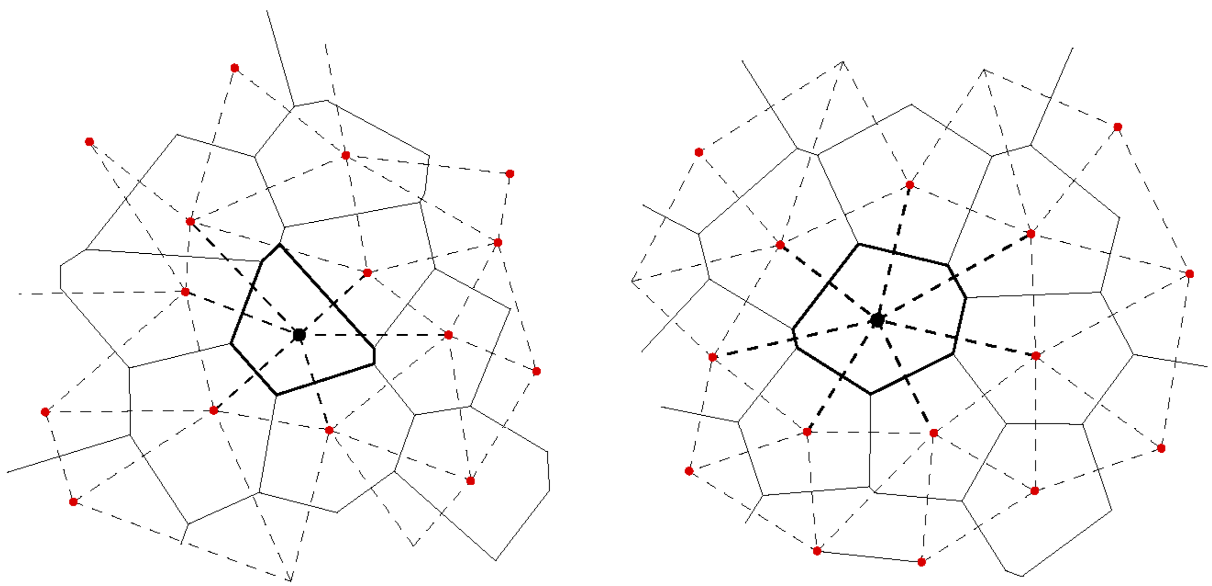
Three types of samples

0. Corner
1. Feature, repulse surface samples via cell clipping
2. Surface, reverse not true



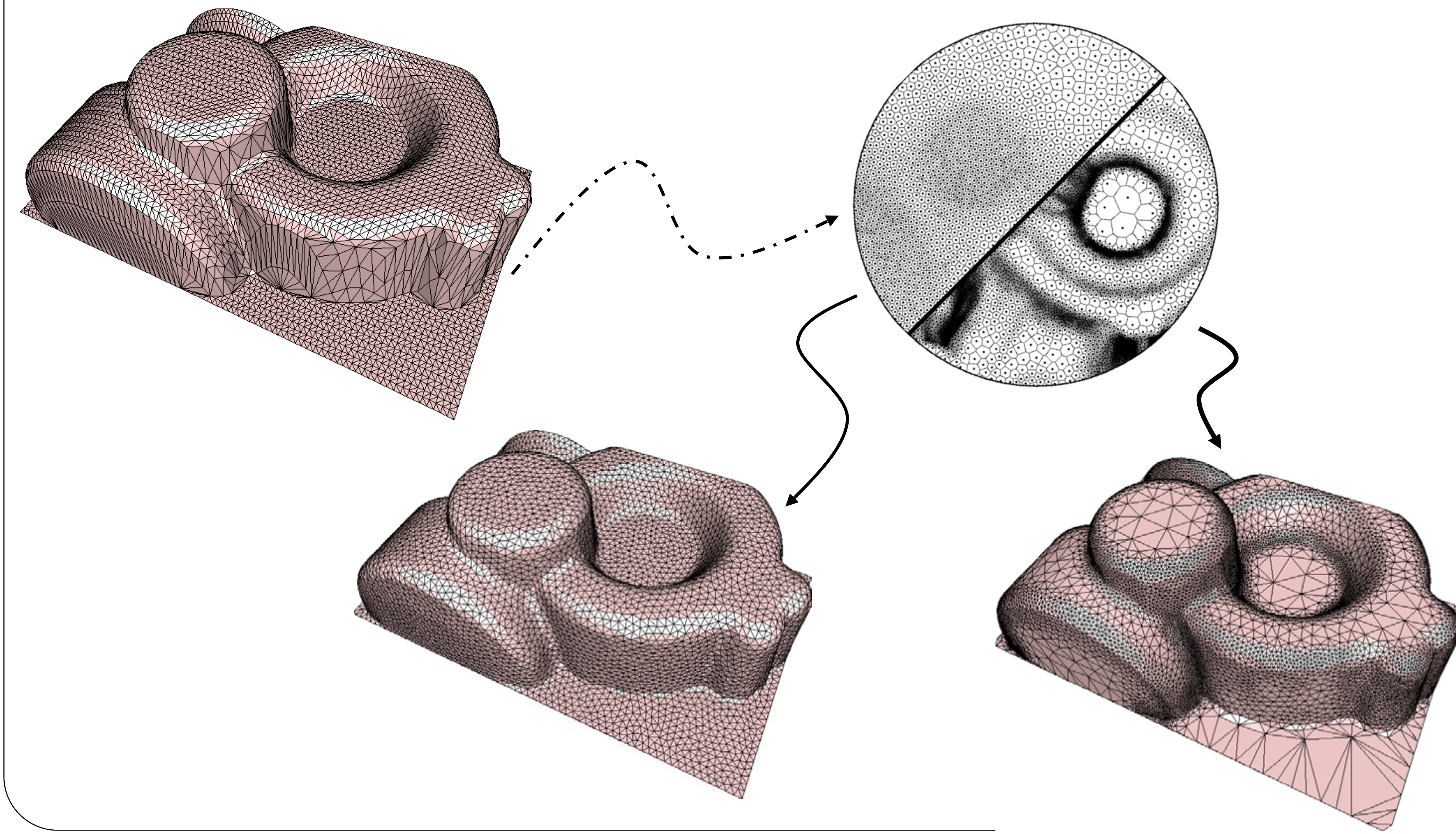
Density approximation

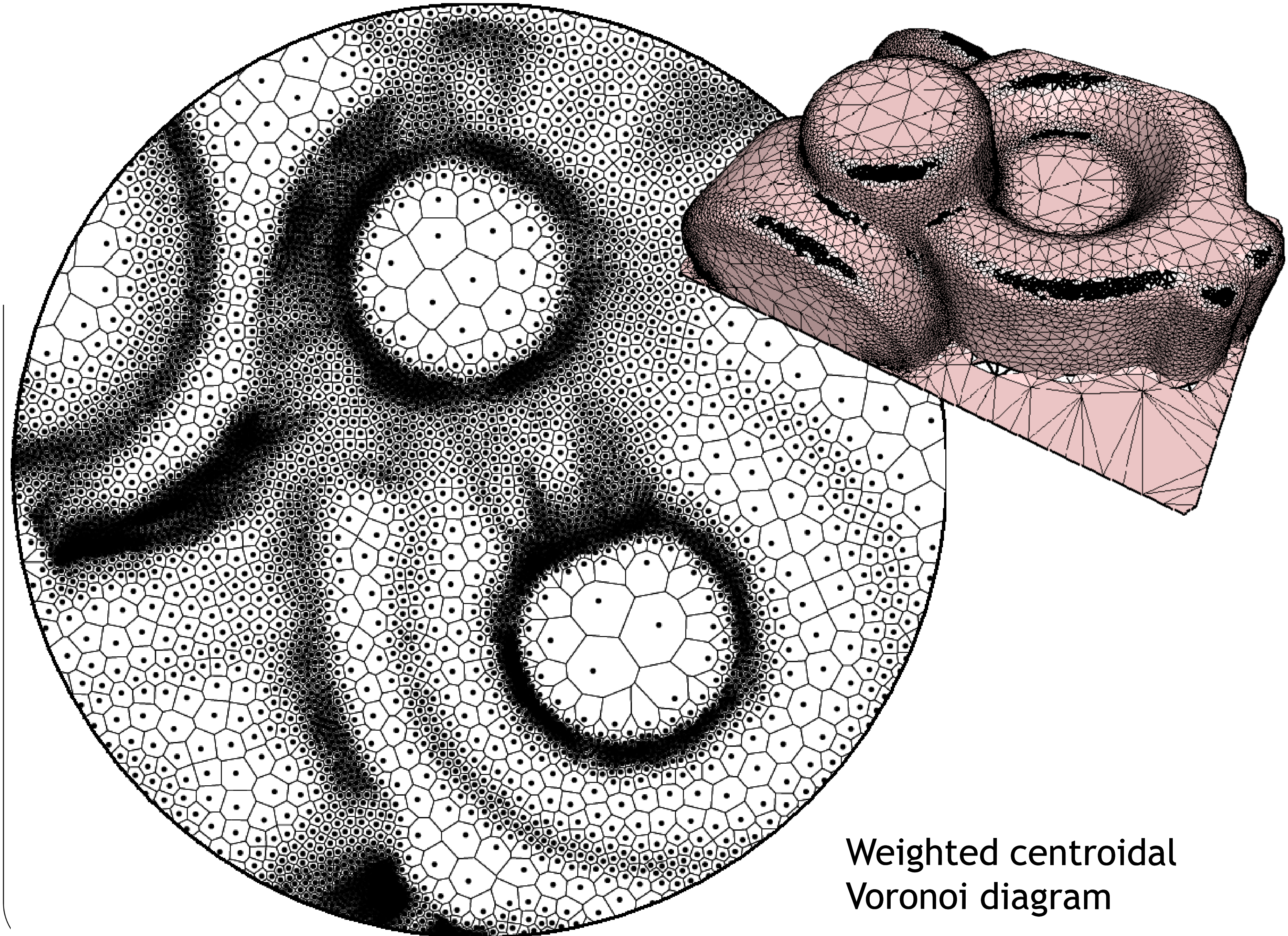
- Piecewise linear on new samples
- Low pass filter density function for undersampling
- Exploit “de Gabriel” properties for better efficiency



Motivation
Previous work
Contributions
Algorithm
Results
Limitations
Conclusions
Future Work

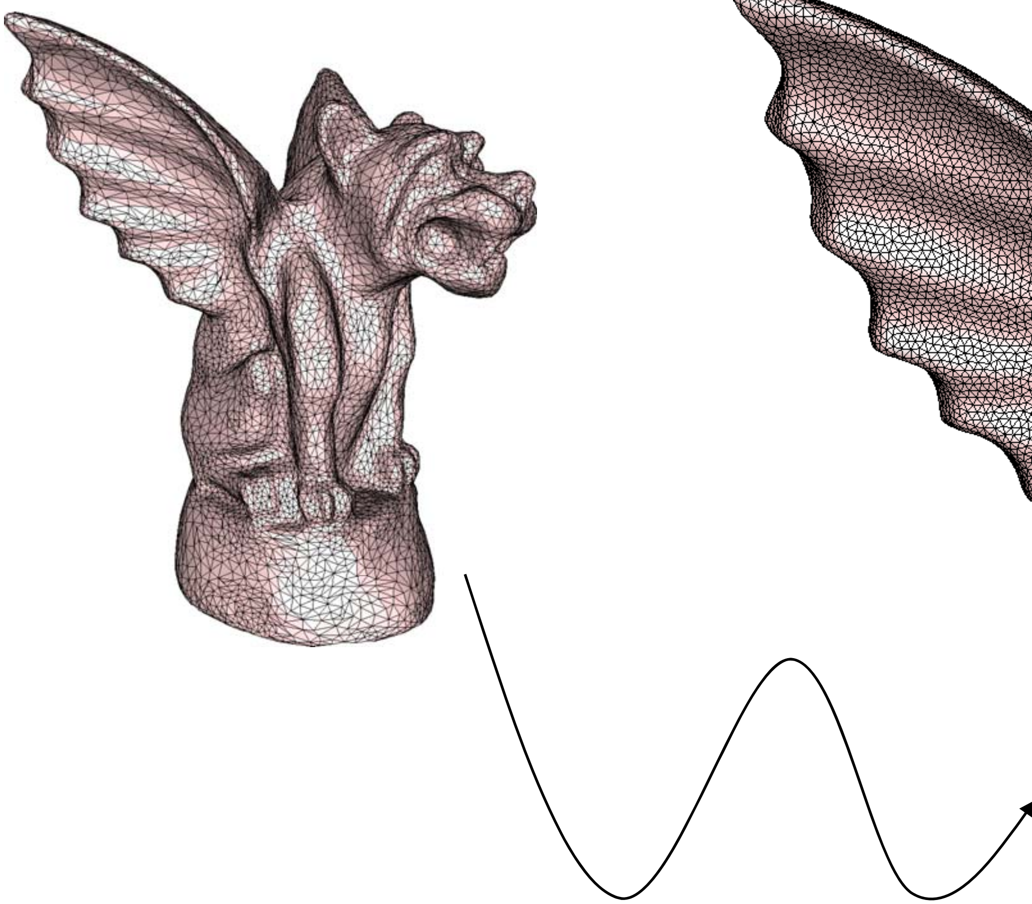
Uniform vs curvature-adapted

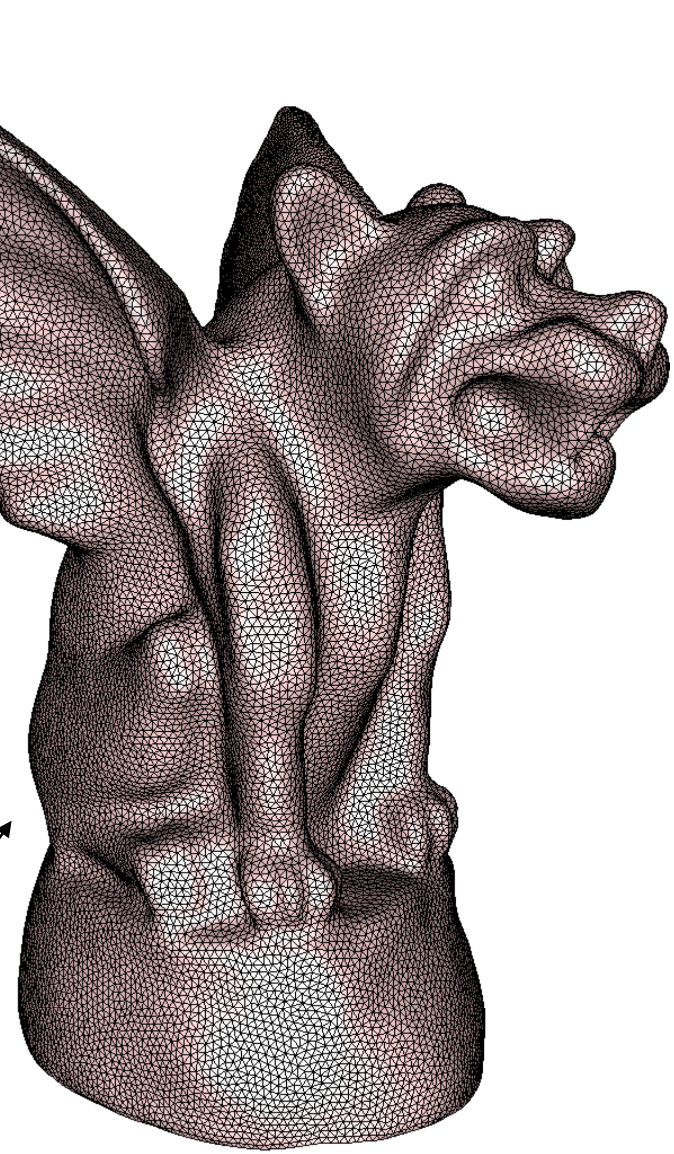




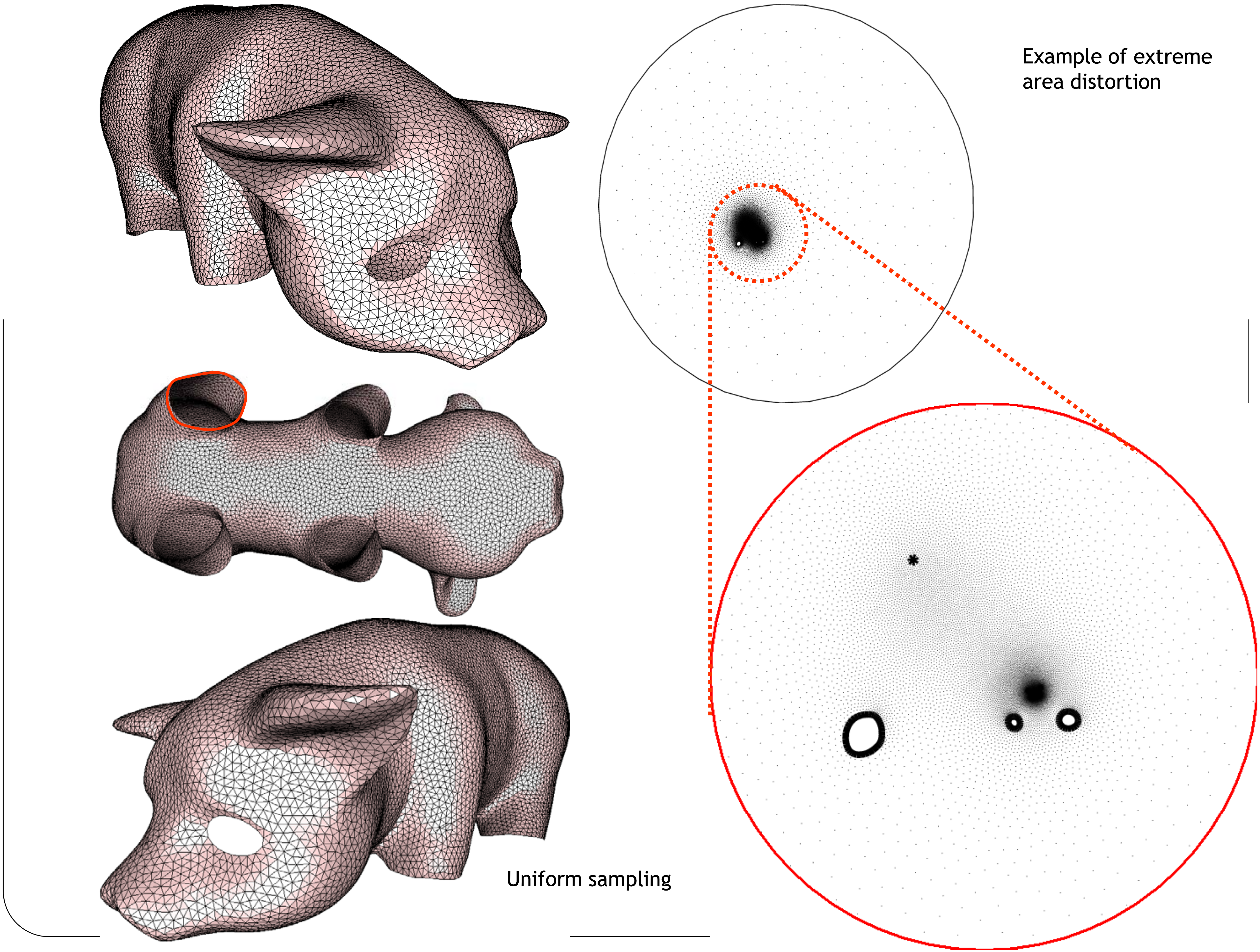
Weighted centroidal
Voronoi diagram

Gargoyle

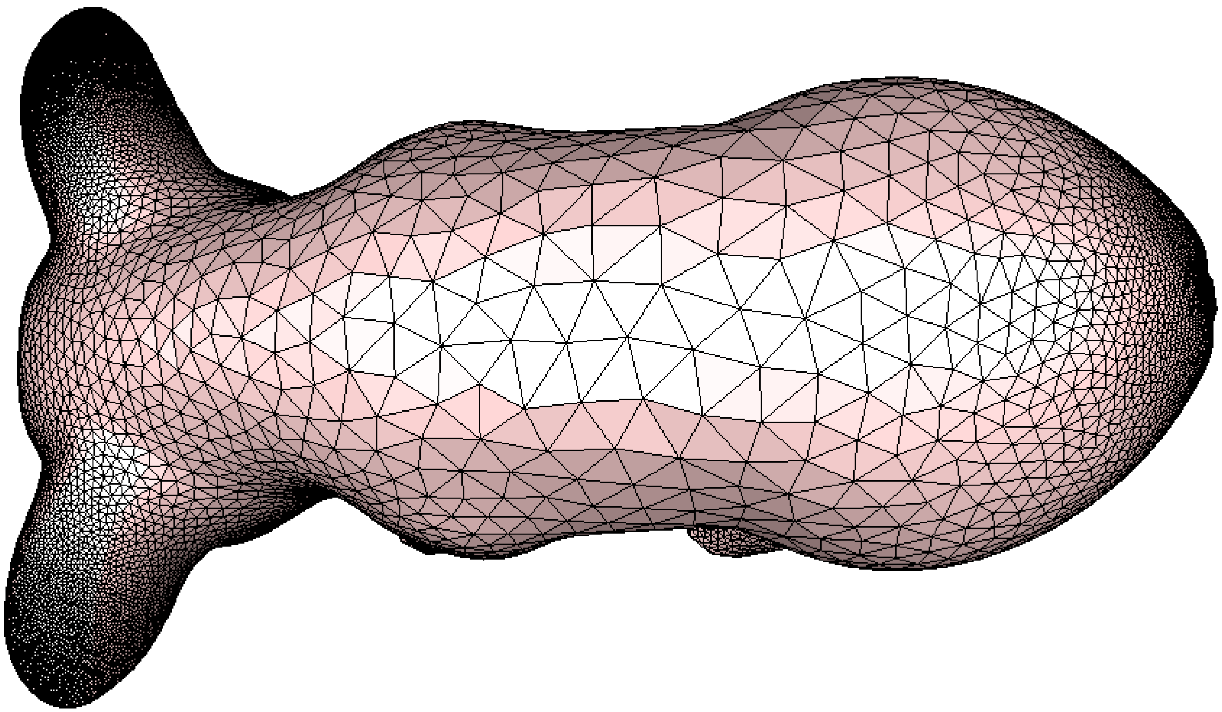


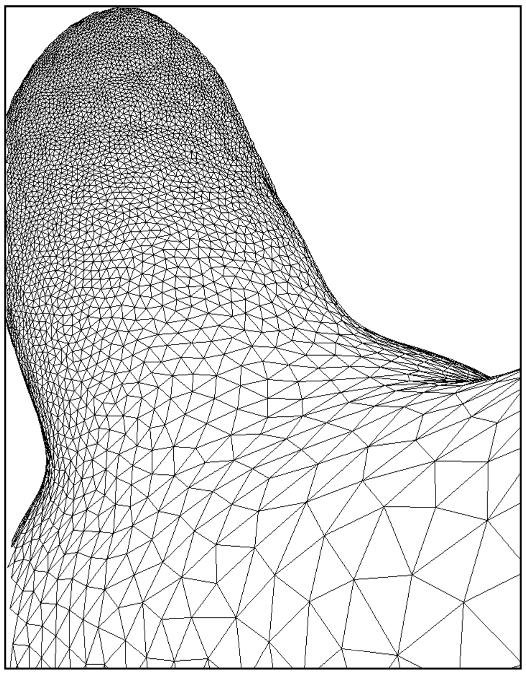


uniform - 30,000 vertices


Example of extreme
area distortion
Uniform sampling

Smooth gradation

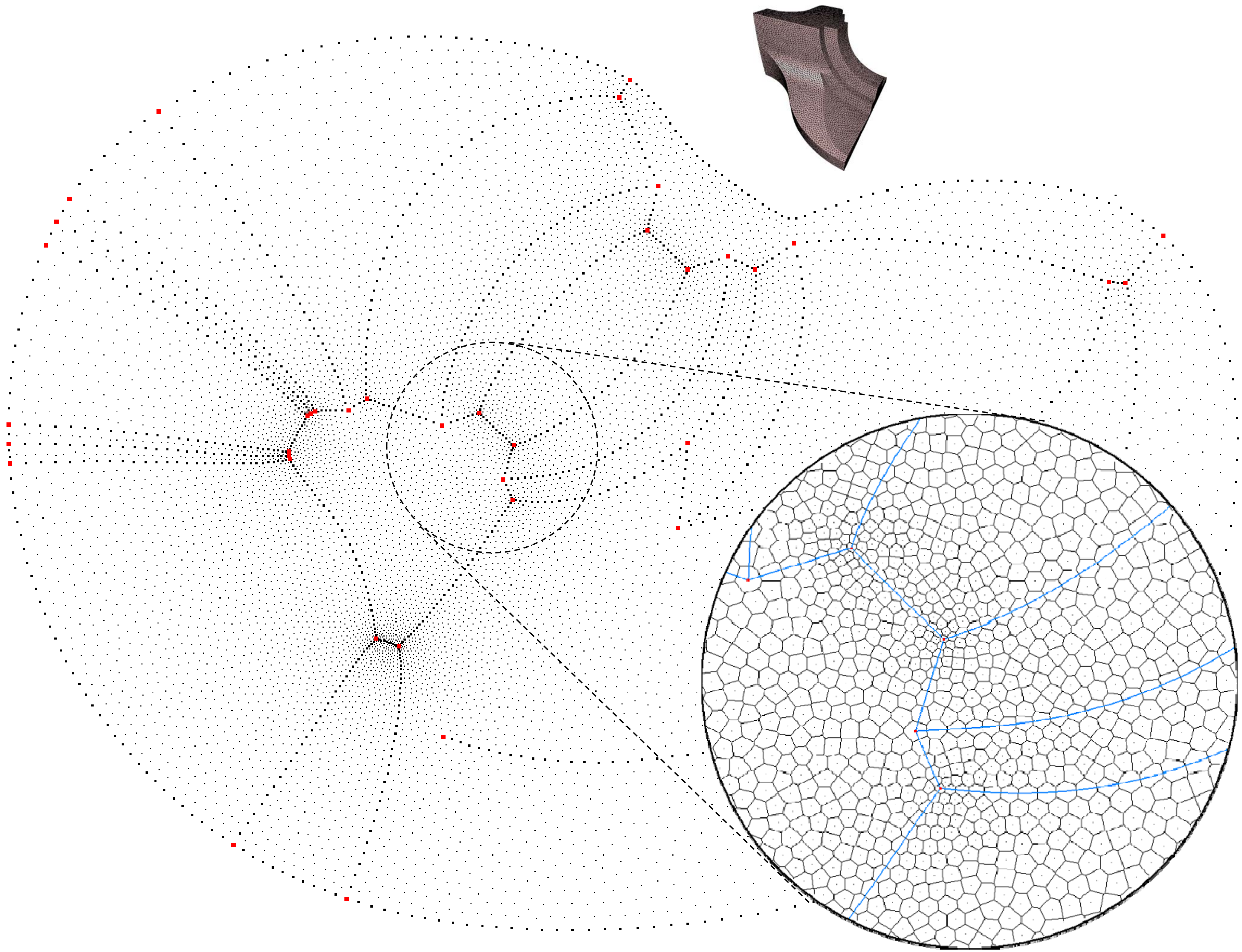


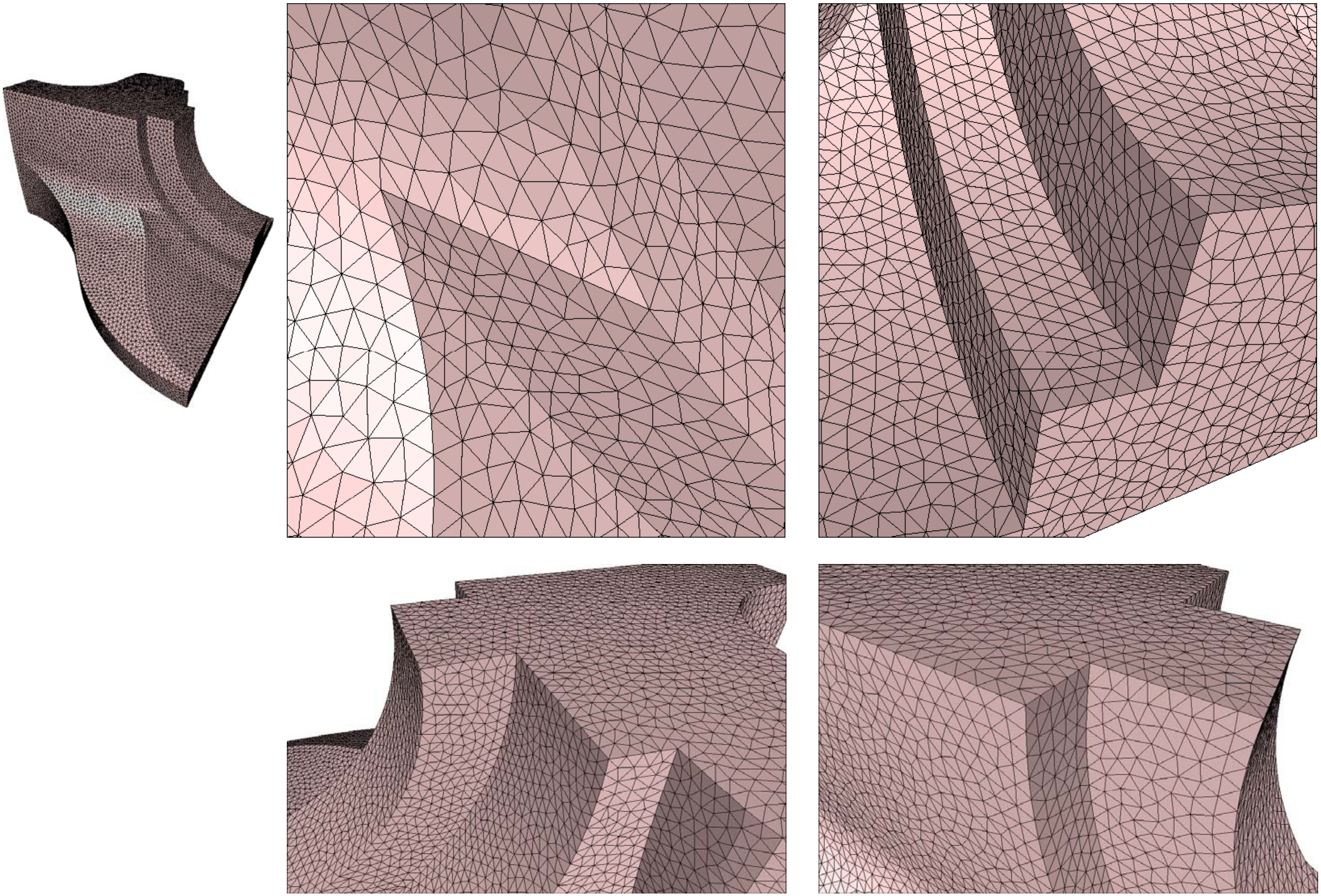


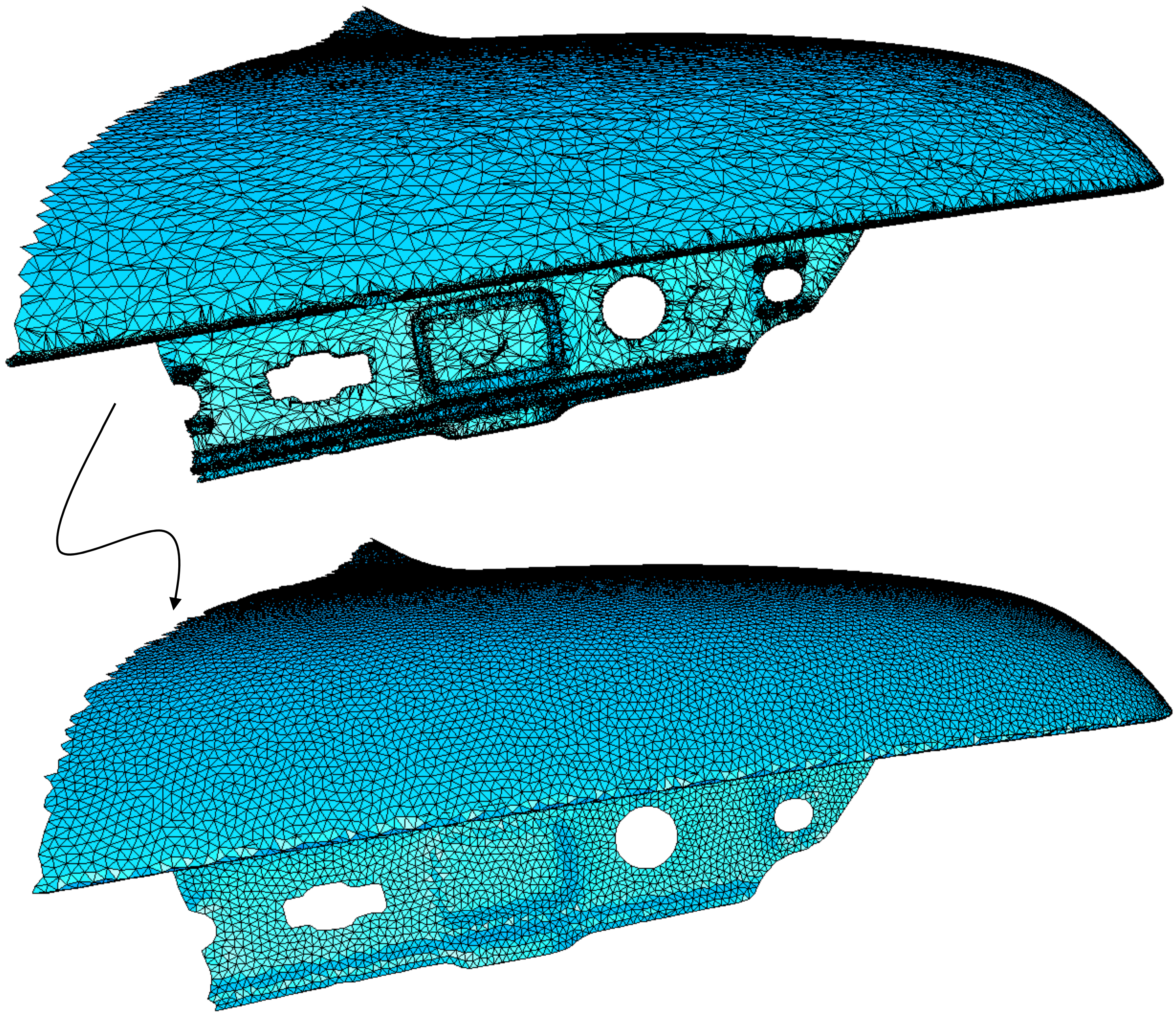
CAD models

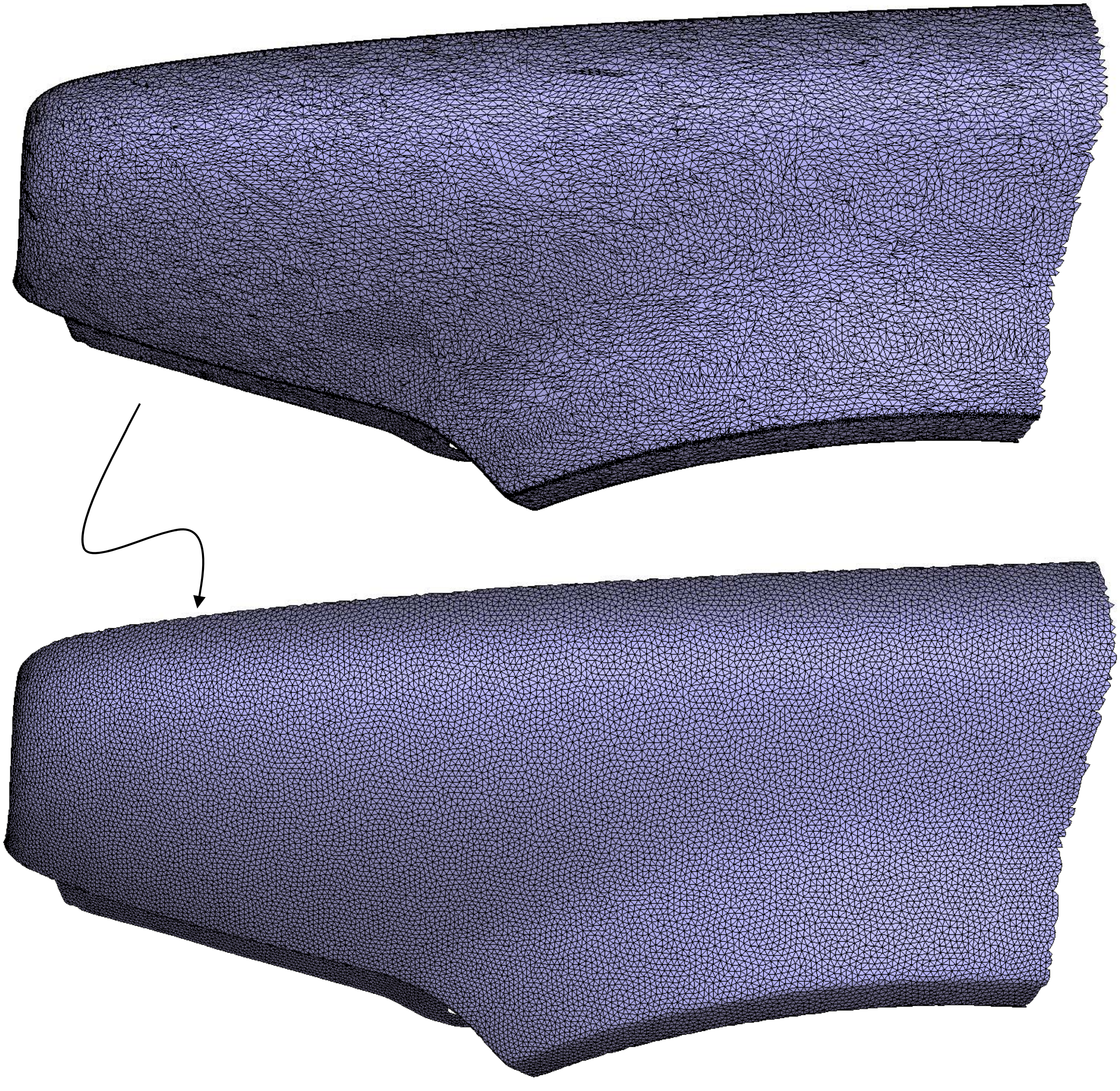
Feature backbones:

- 1D error diffusion
- arc-length parameterization of backbones
- 1D WCVD



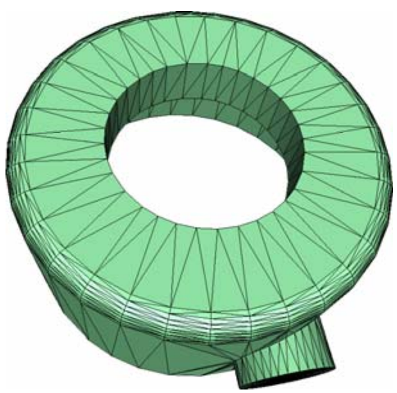




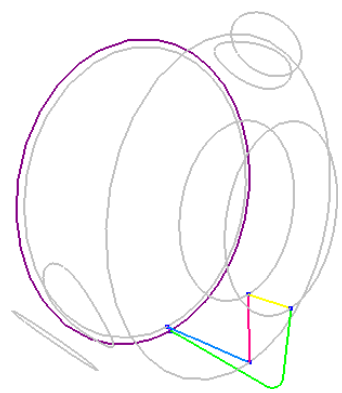


Genus>0 model

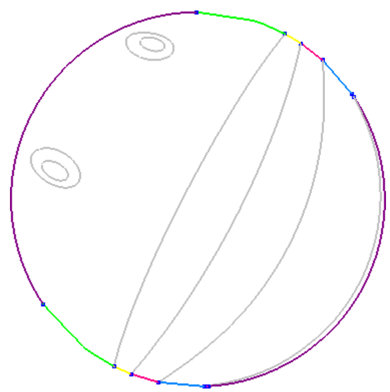
- cutting -> cut graph
- add cut graph to feature skeleton
  -> twin backbones associated pairwise
- synchronize sampling along twin backbones to guarantee stitching



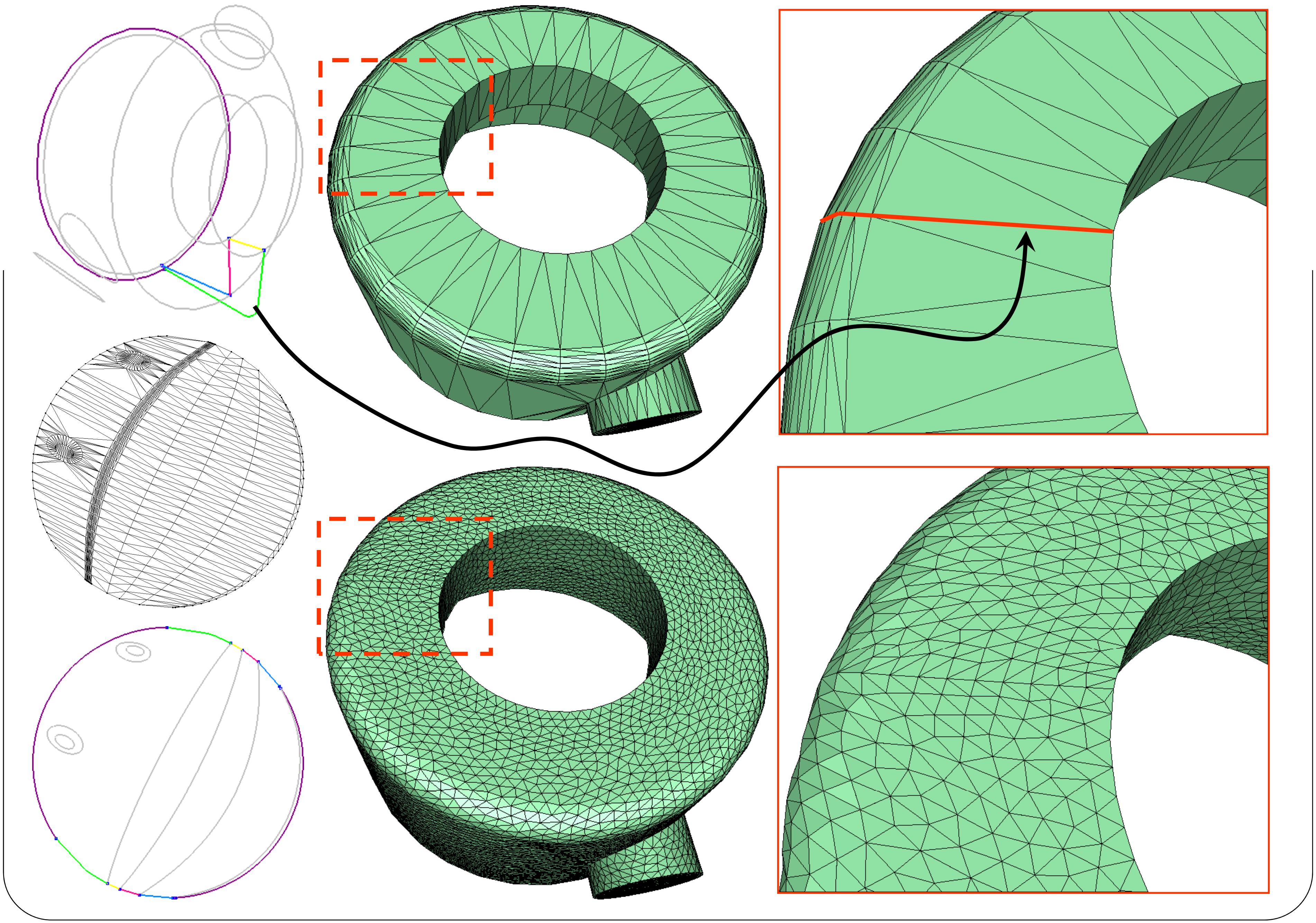
genus 1



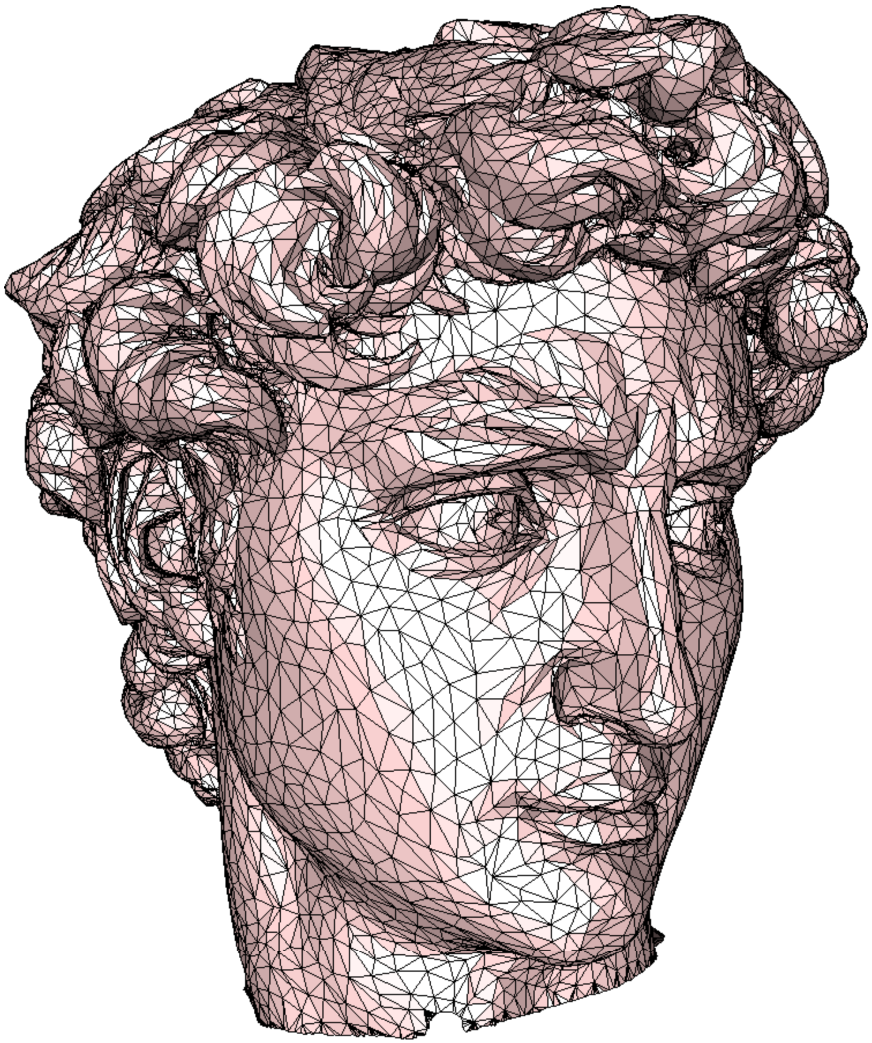
cut graph

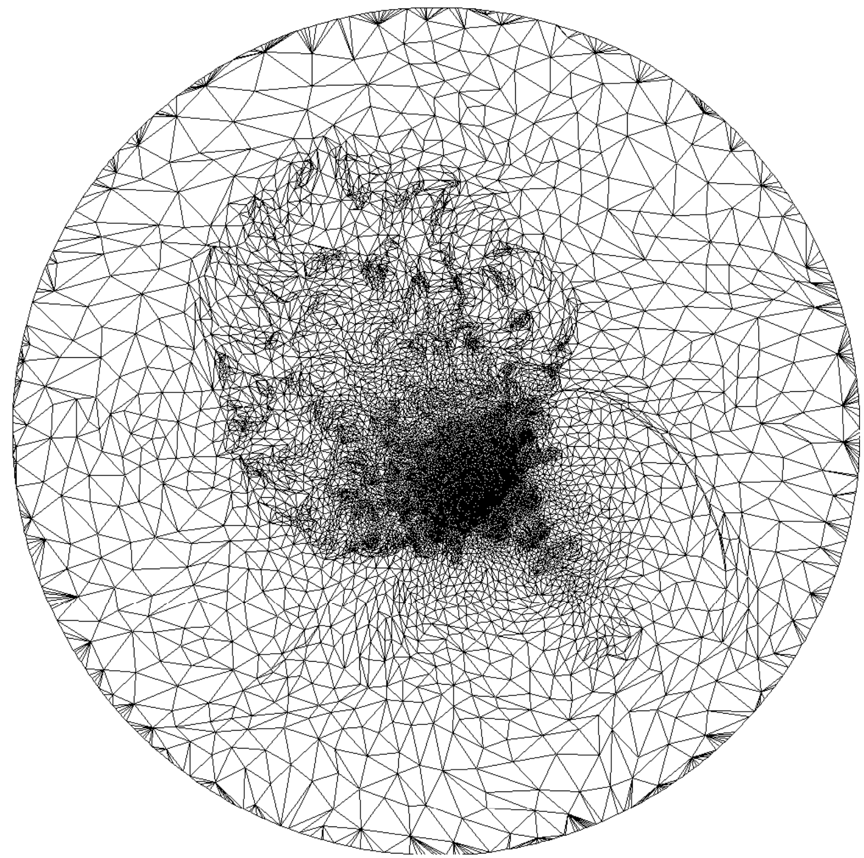


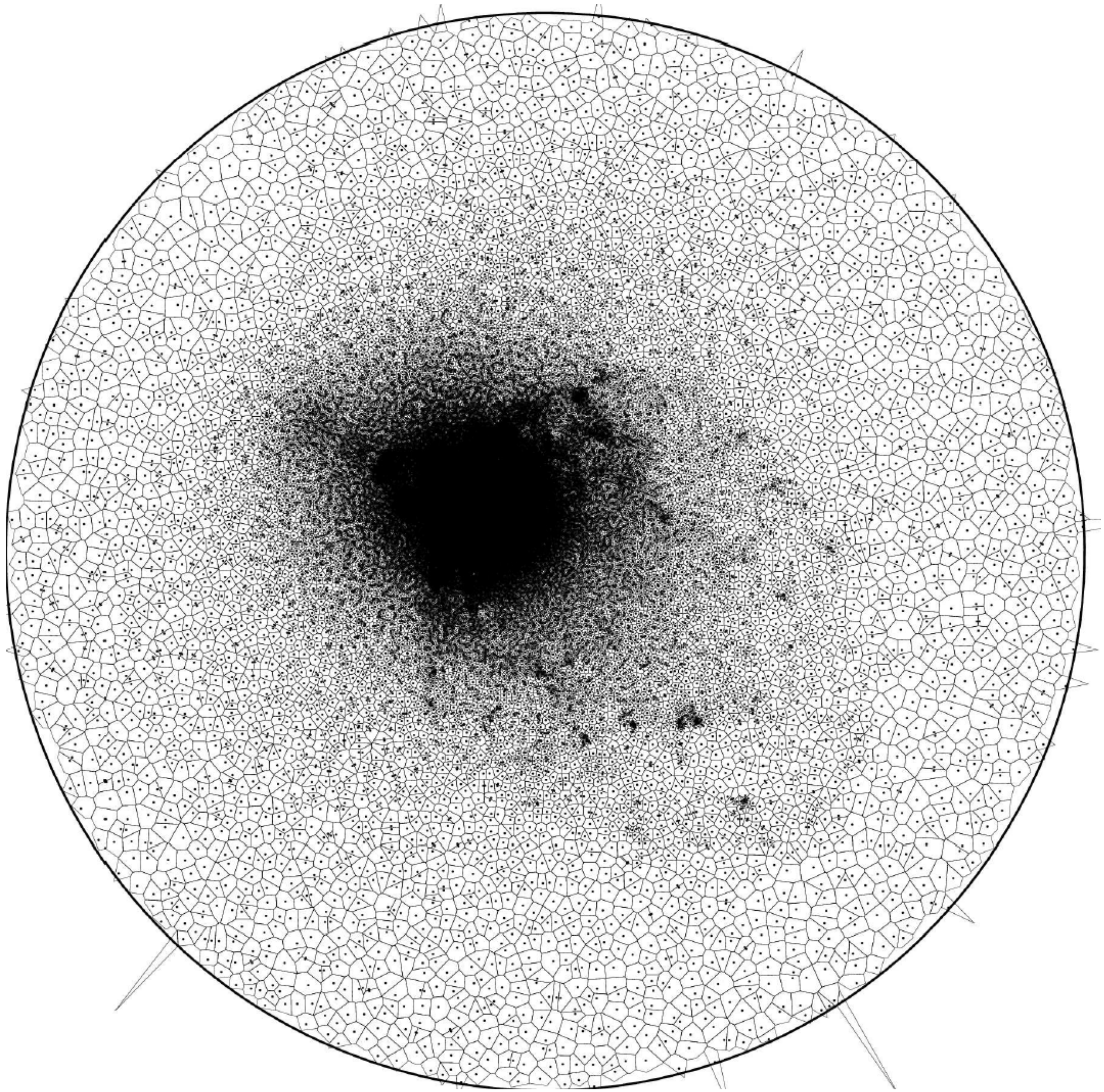
parameter space



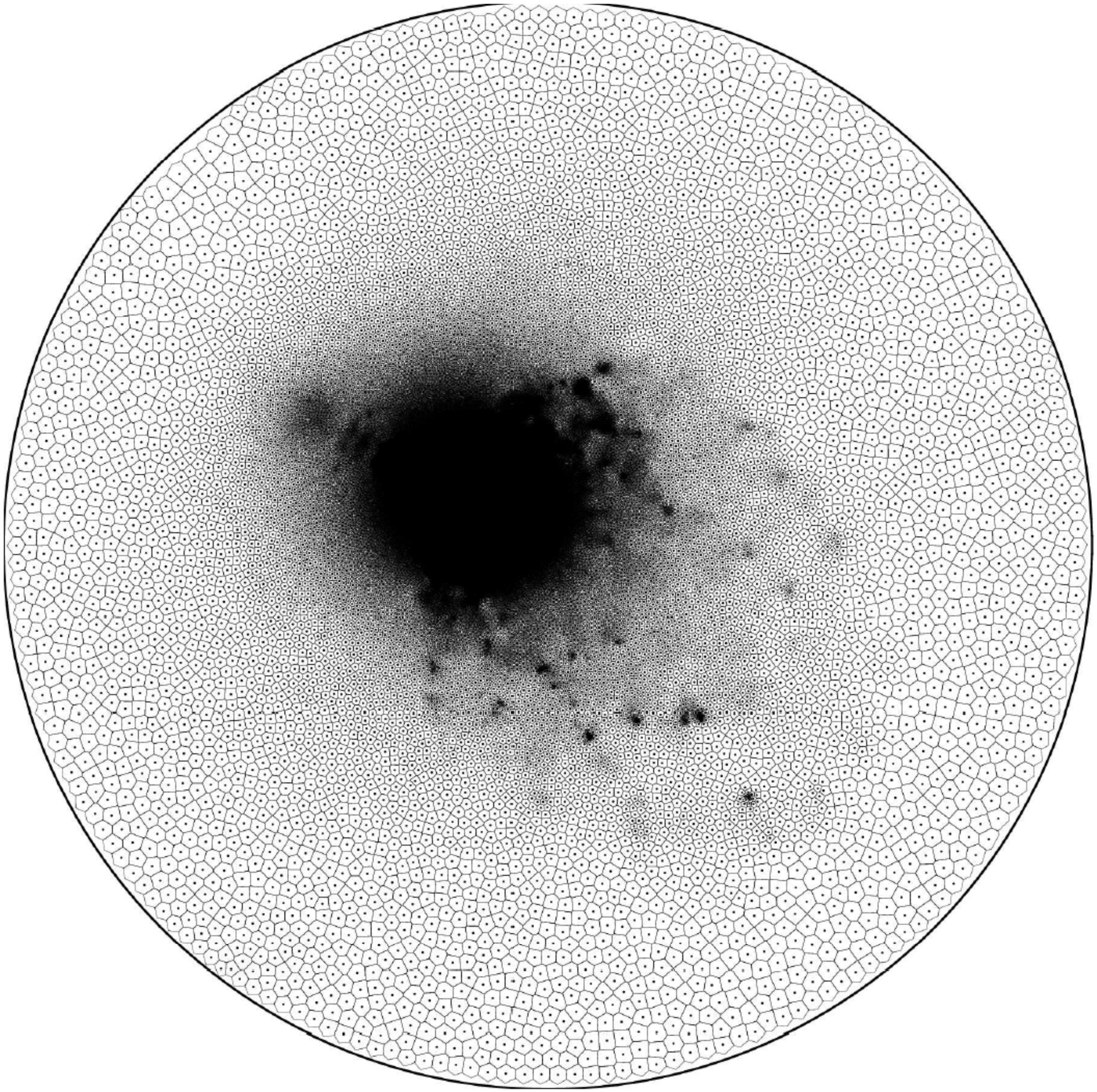
David model [Digital Michelangelo]





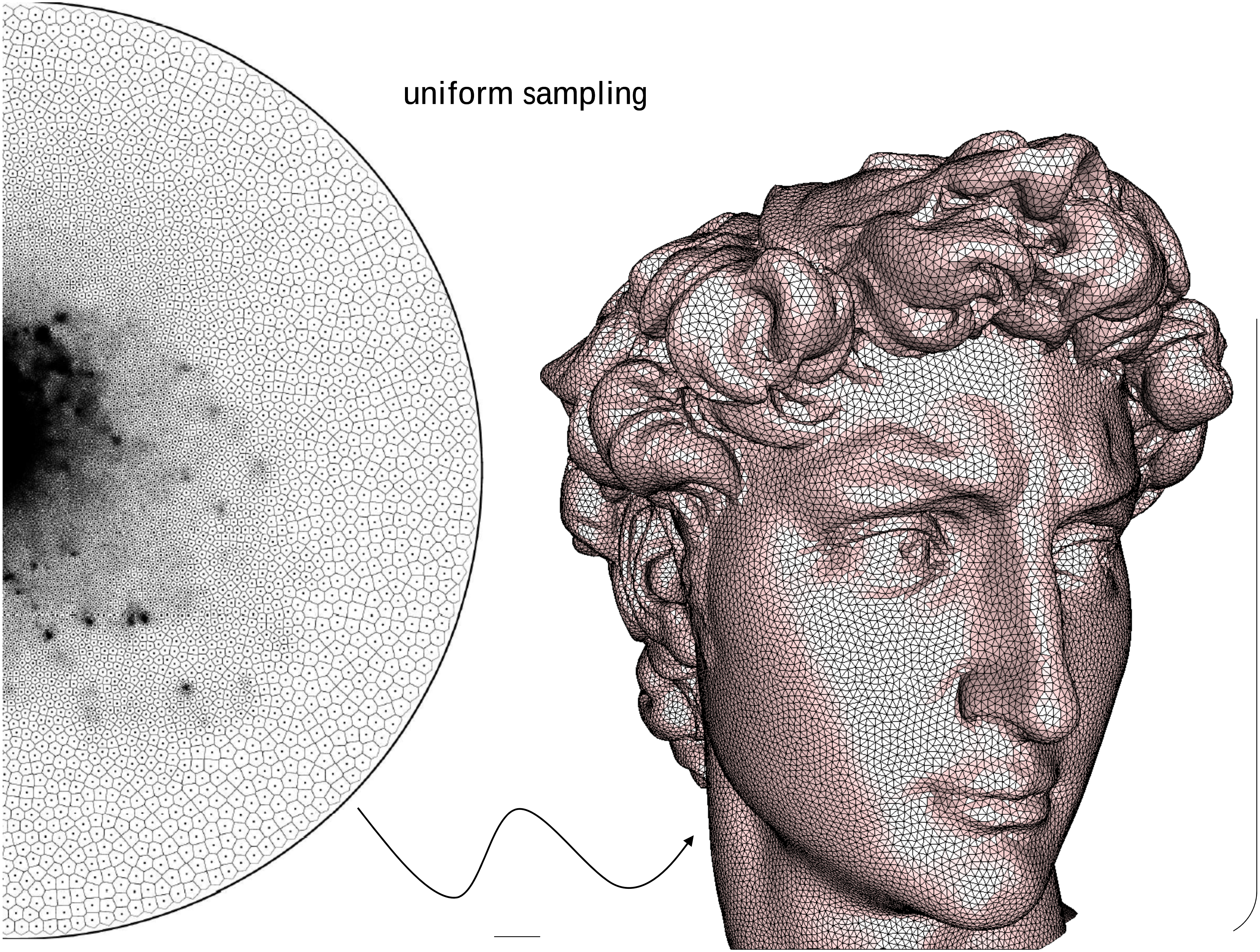


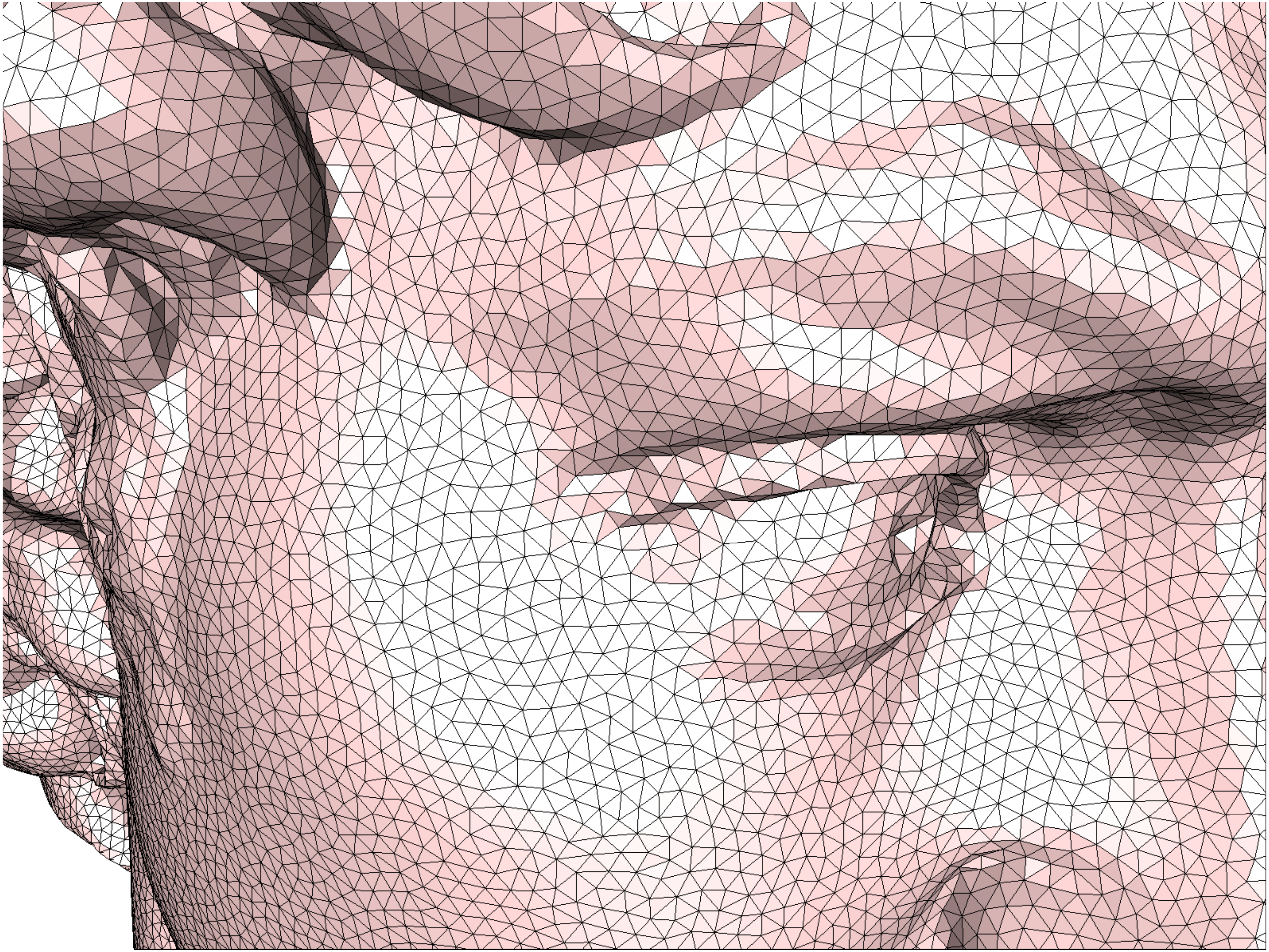
Sample repartition
by error diffusion
(50,000 vertices)

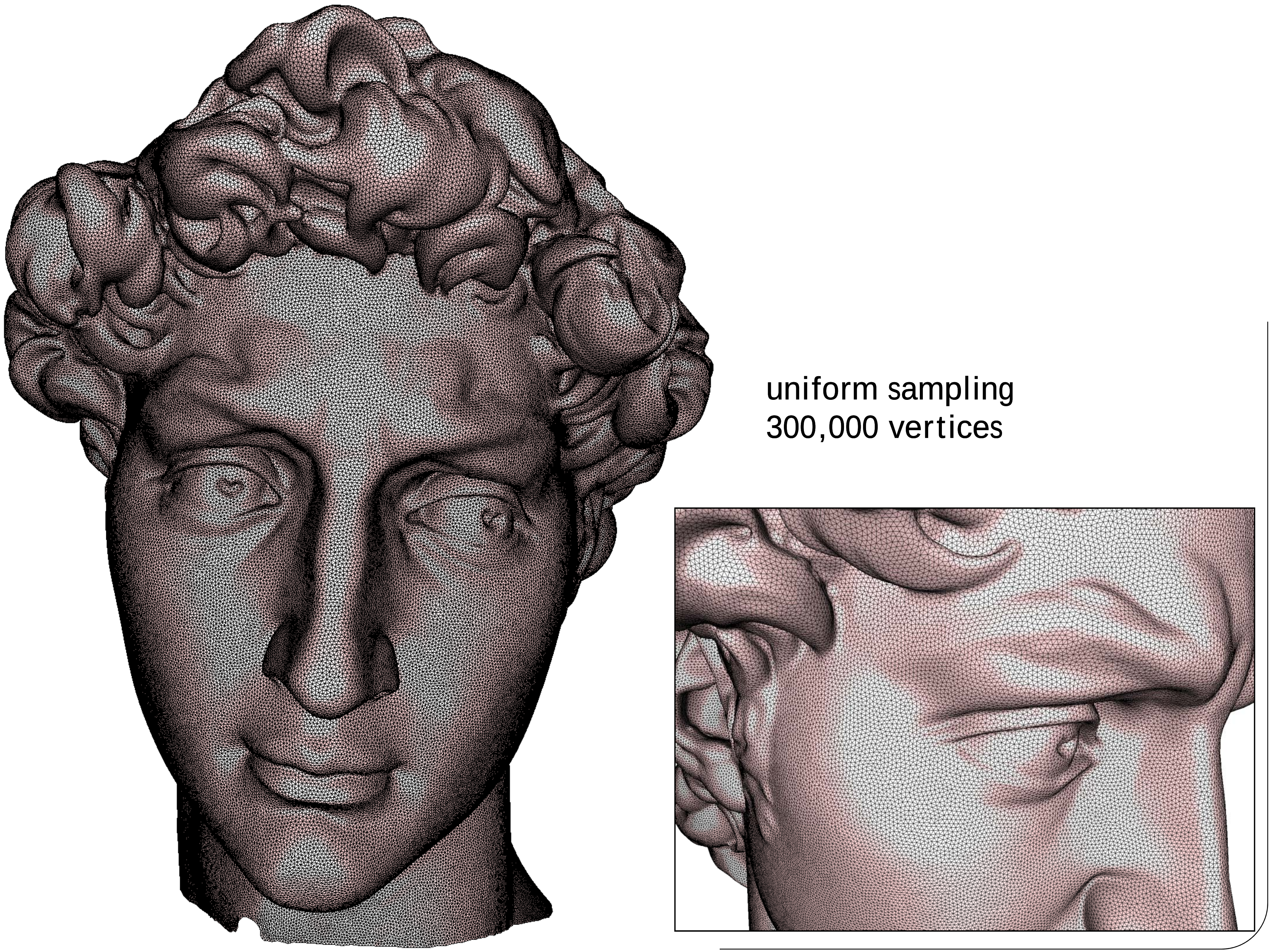


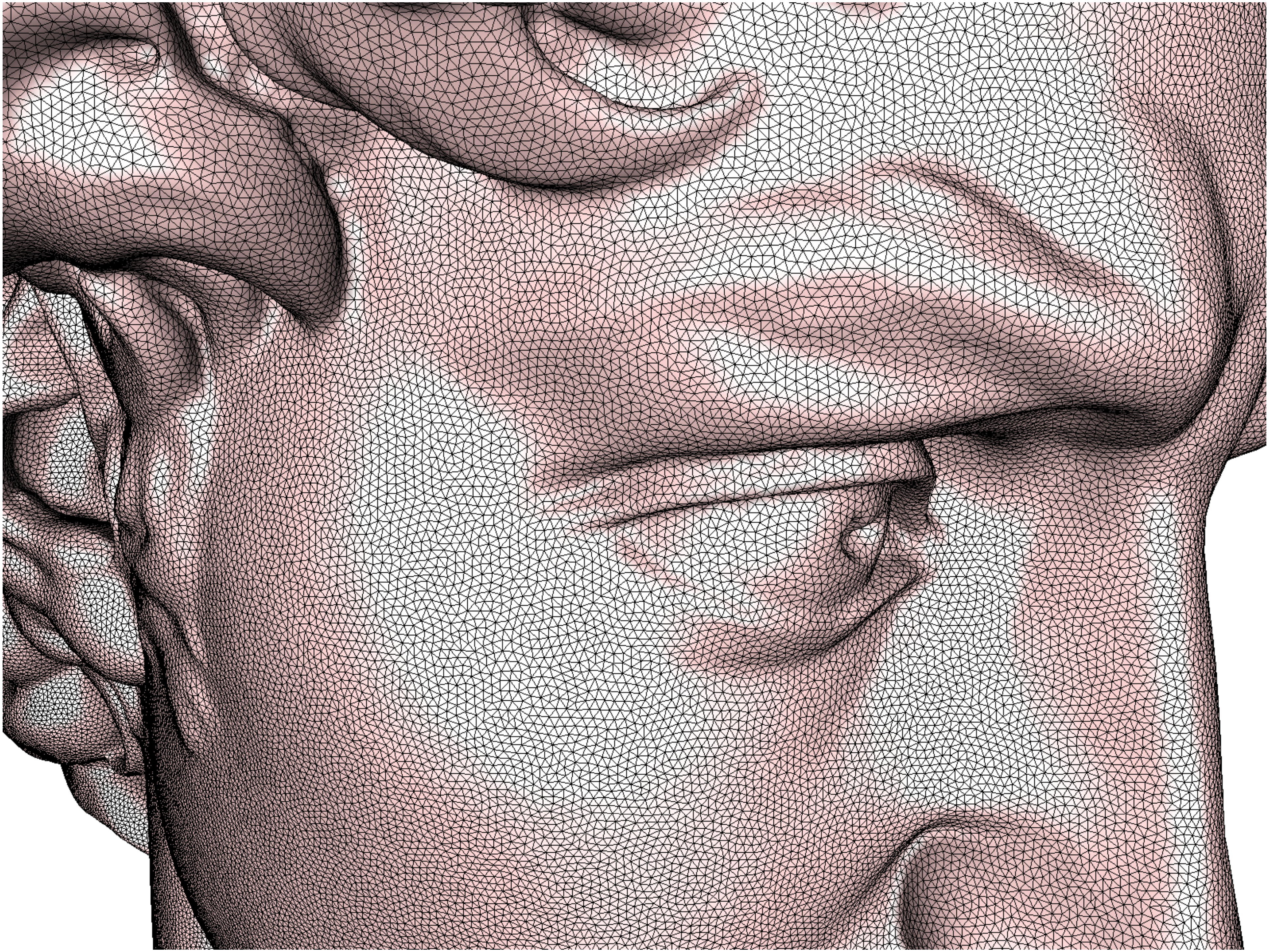
Sample placement
by WCVD

uniform sampling

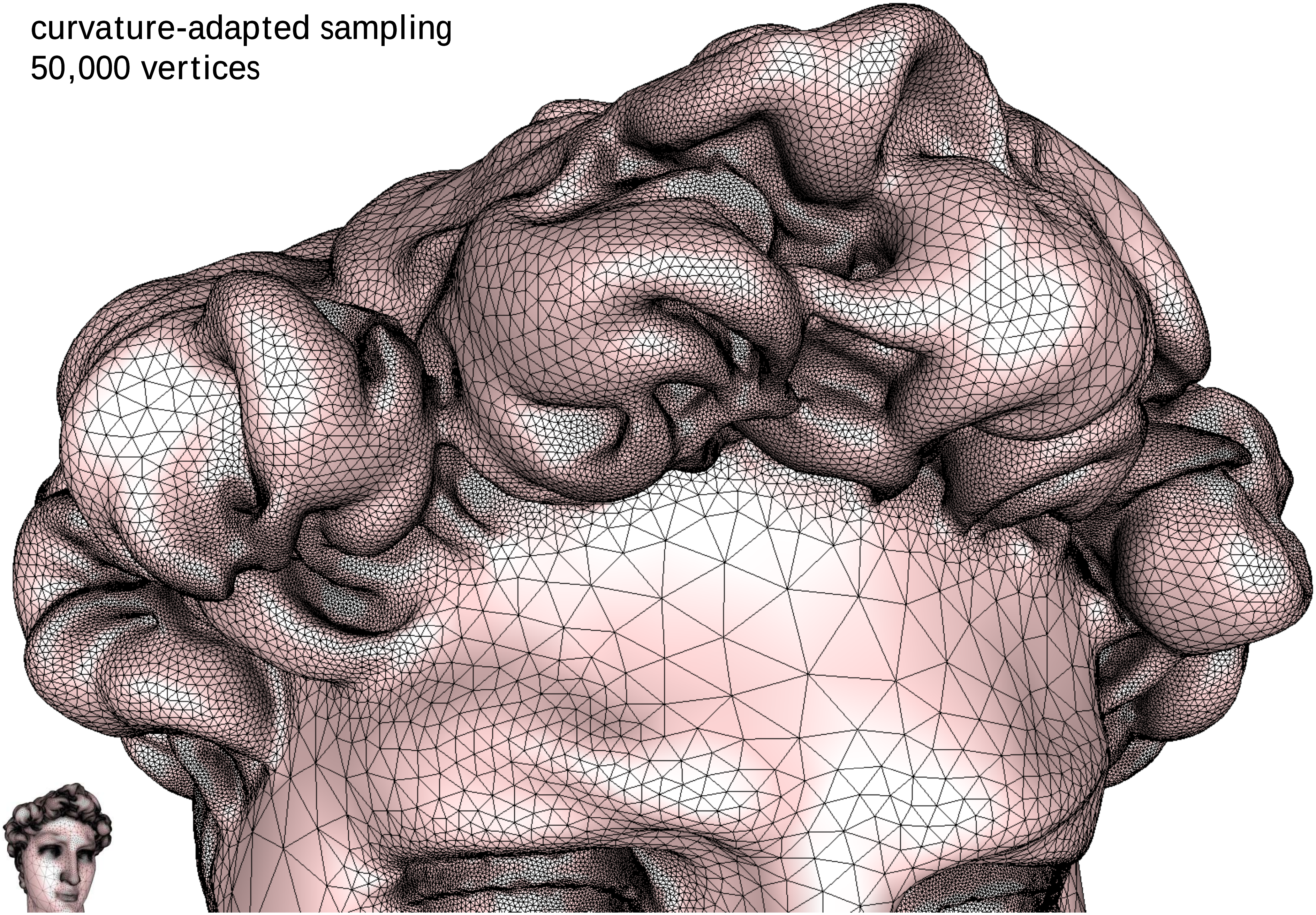


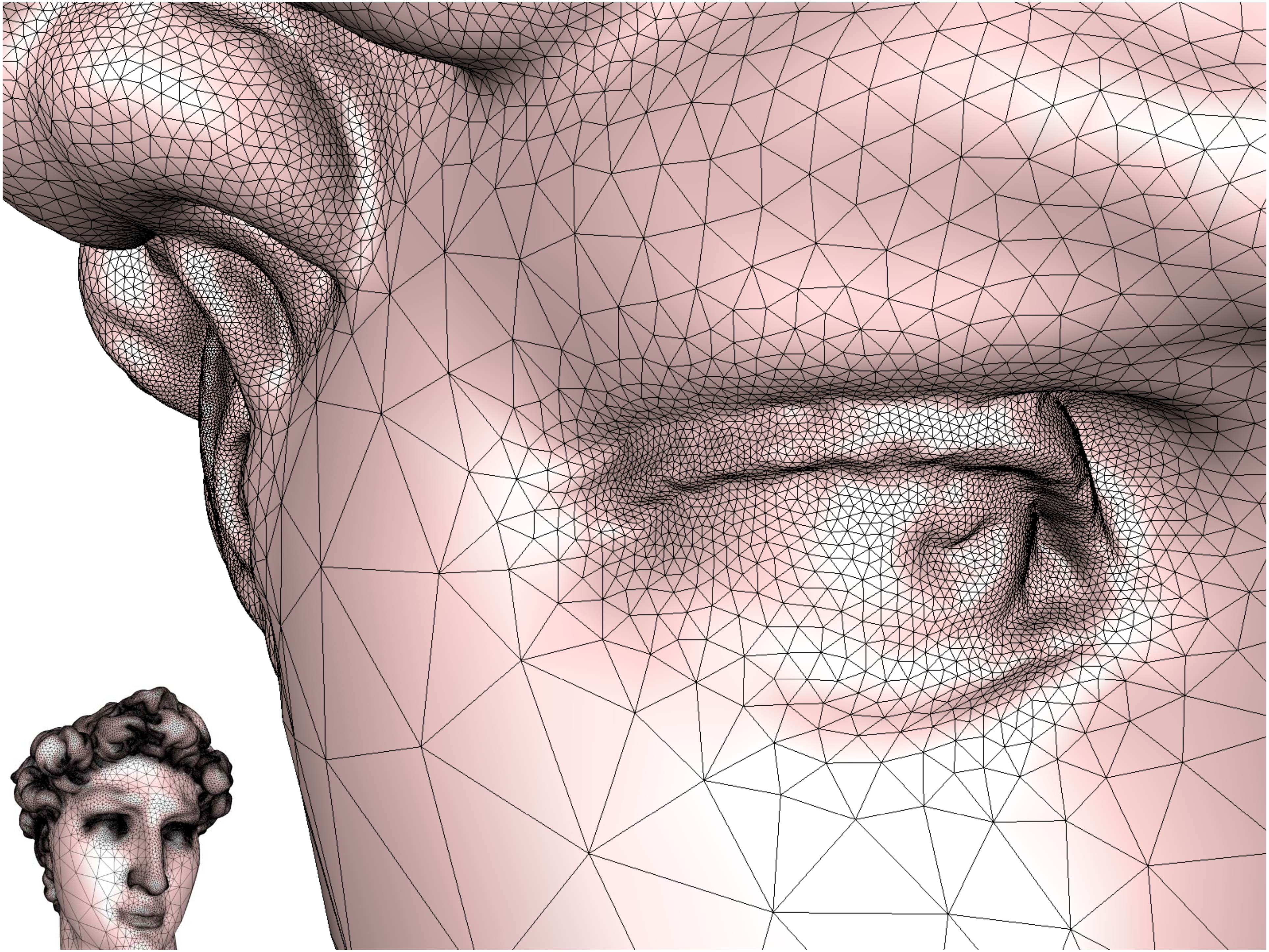


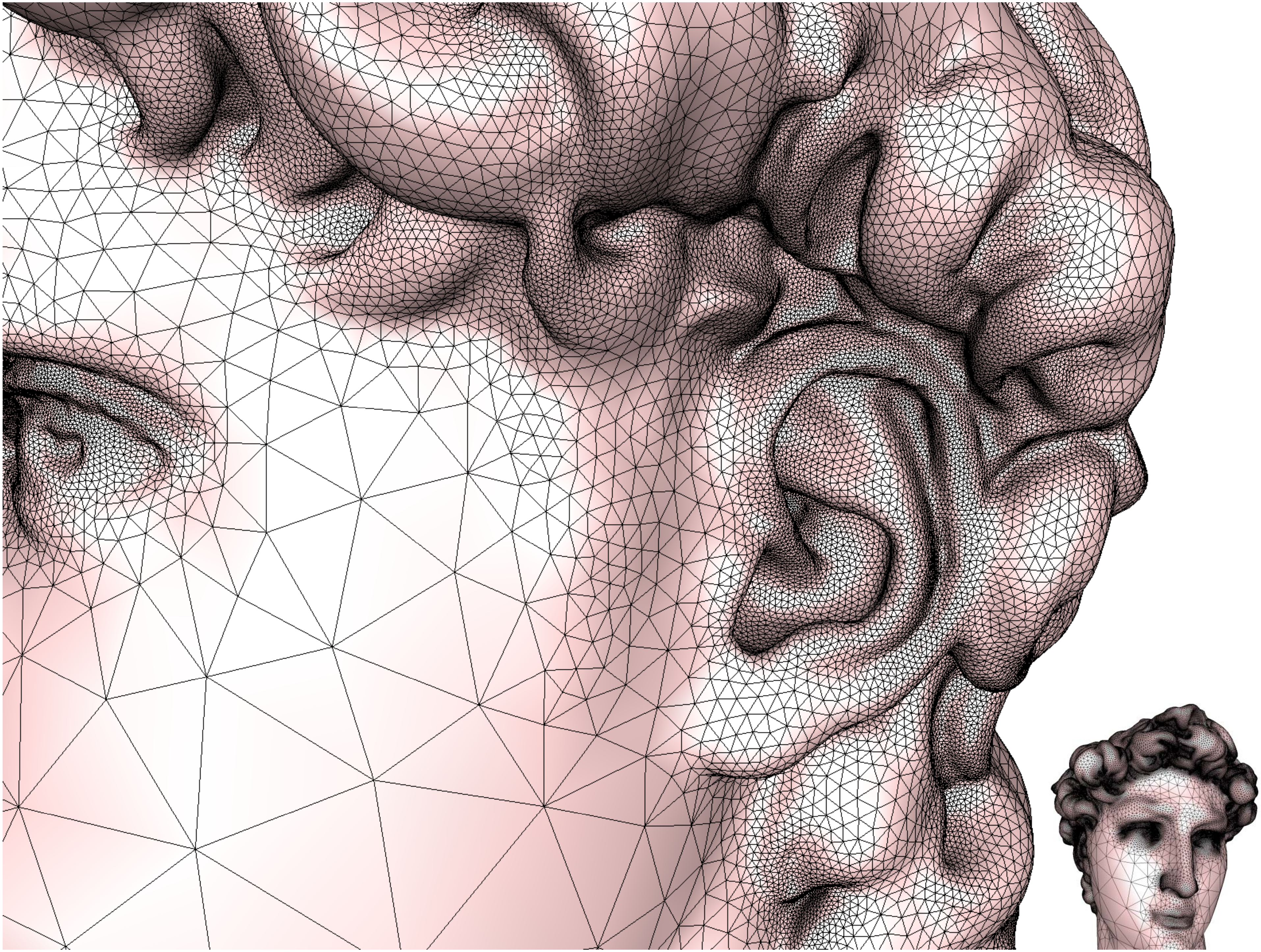

uniform sampling
300,000 vertices



curvature-adapted sampling
50,000 vertices







Motivation

Previous work

Contributions

Algorithm

Results

Limitations

Conclusions

Future Work

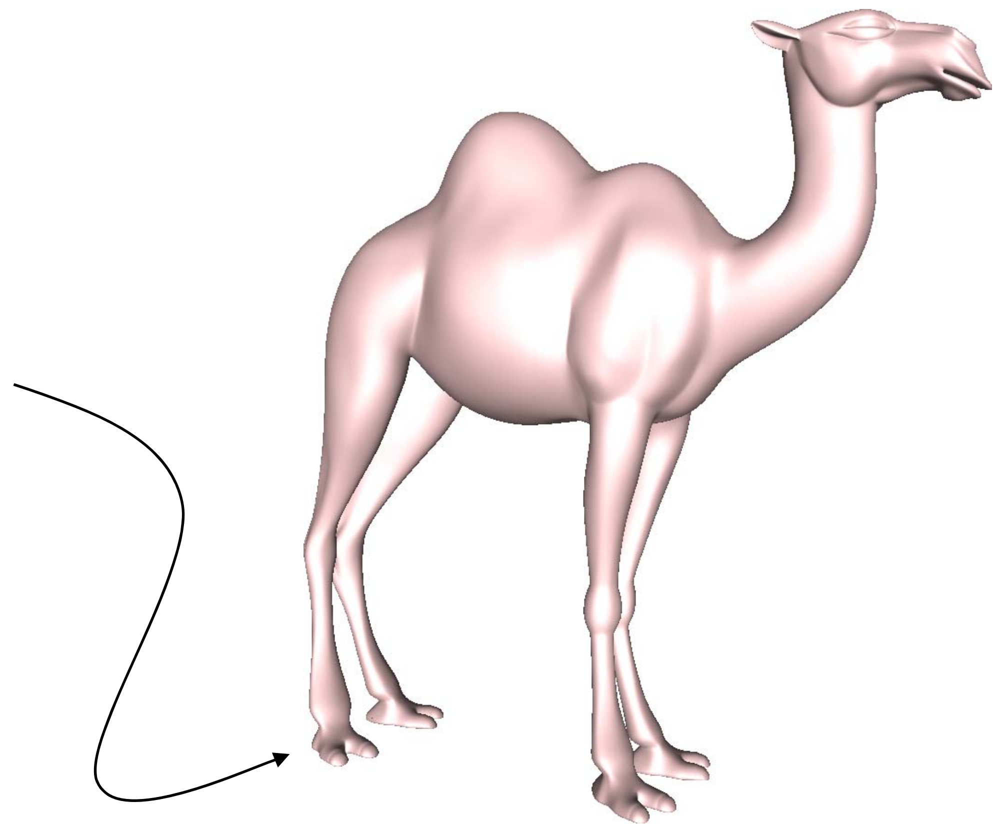
Limitations

- Parameterization
  - still some numerical issues for huge models
  - quality of sampling is *very dependent* on the quality of the parameterization
- Complex genus or closed surface
  - requires surface cutting (difficult task)
  - process "curve sampling " along the cut graph
  - makes the implementation trickier (seaming backbones, twin samples to synchronize for stitching, branching vertices, etc.)

Limitations

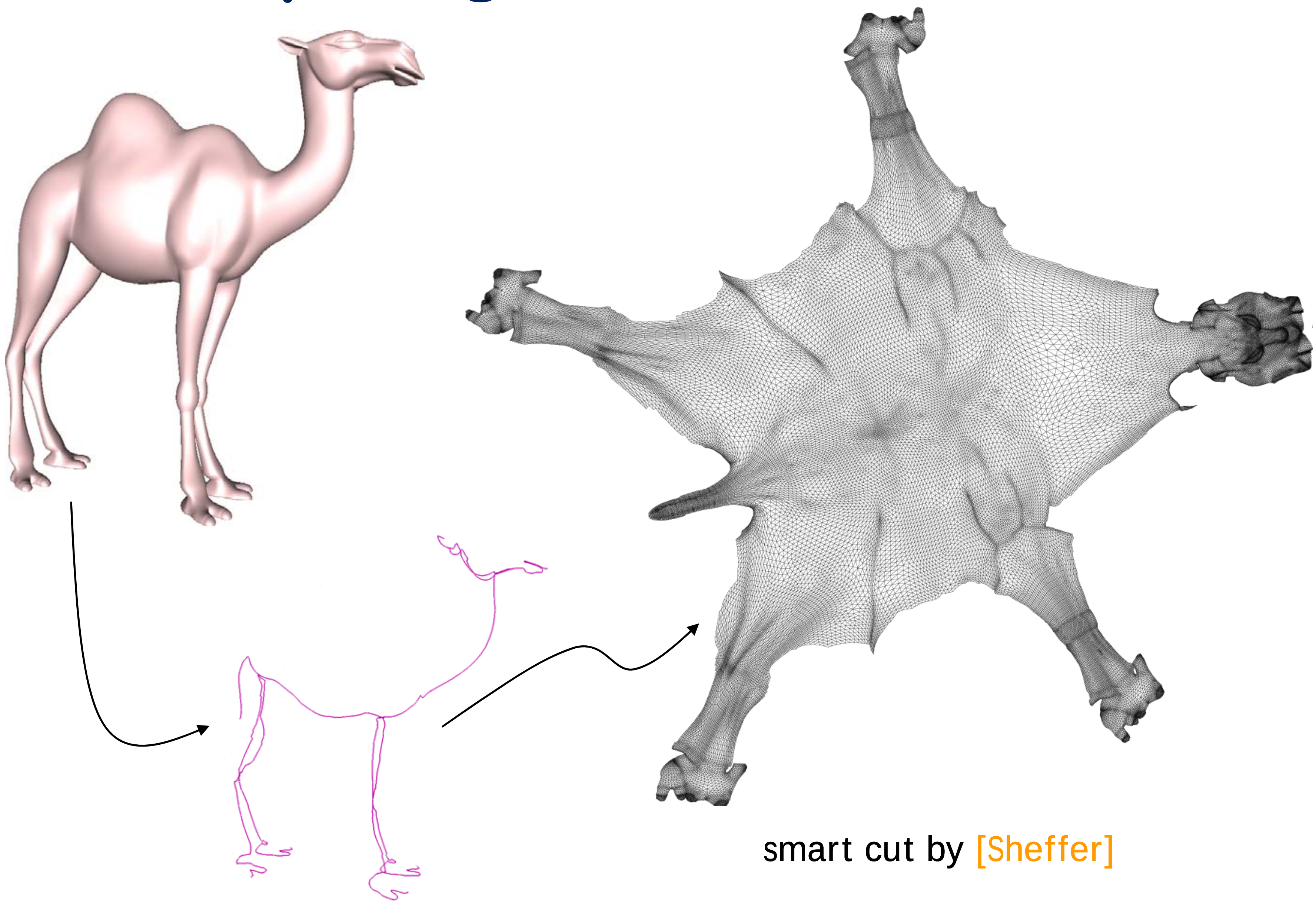
The Camel

- Closed
- Genus 0
- Sock-like shapes



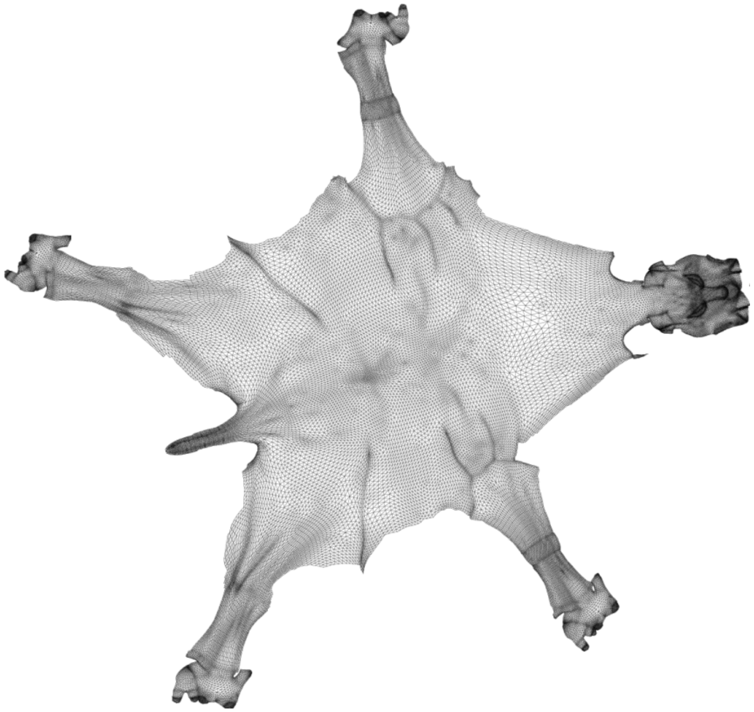
how to cut it? ->

Camel pelting

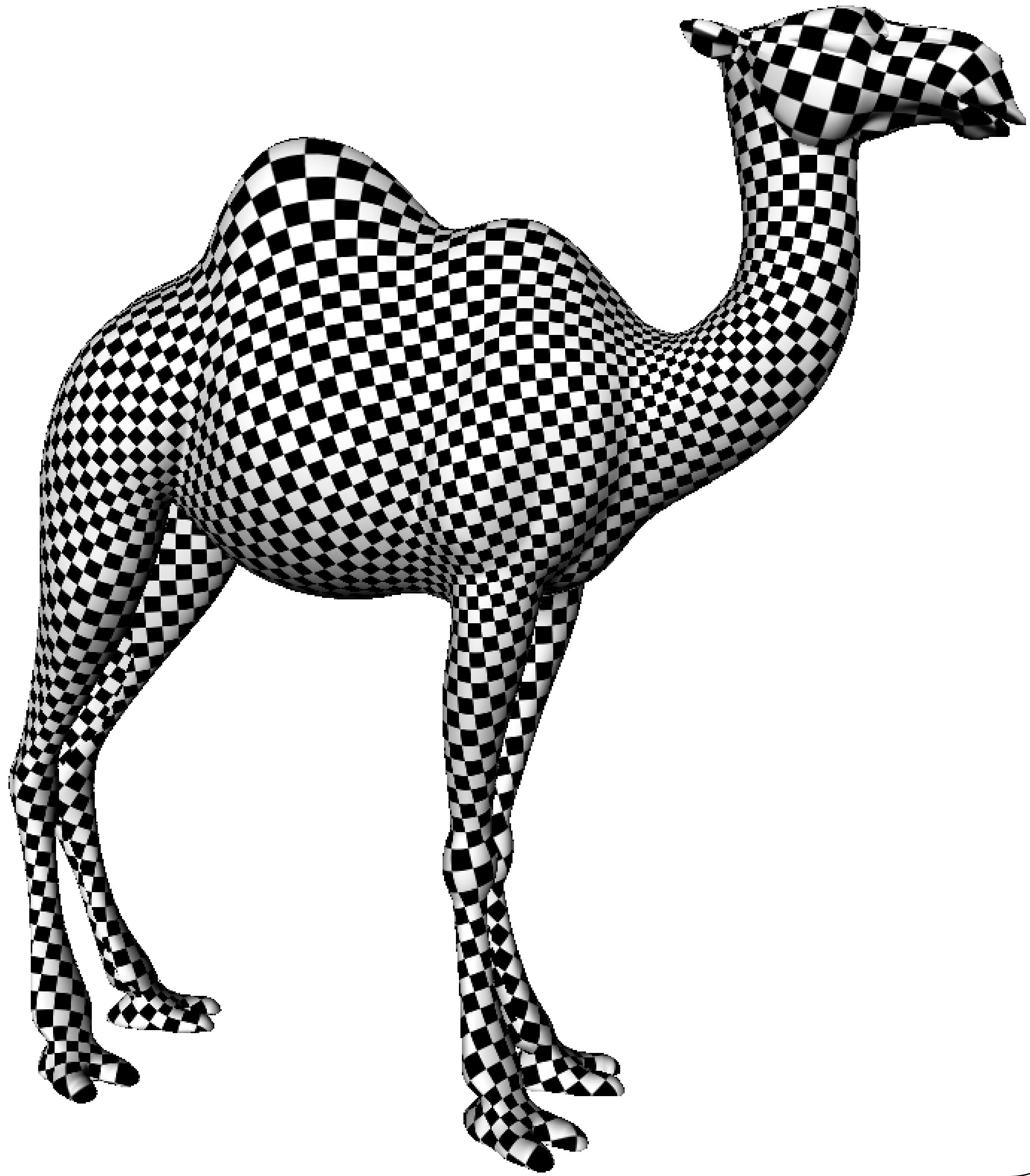


smart cut by [Sheffer]

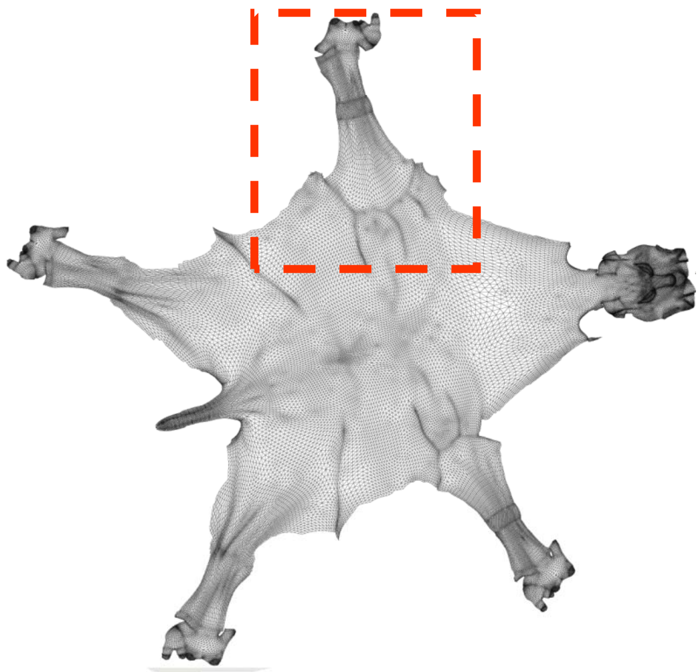
Smart pelting & Parameterization

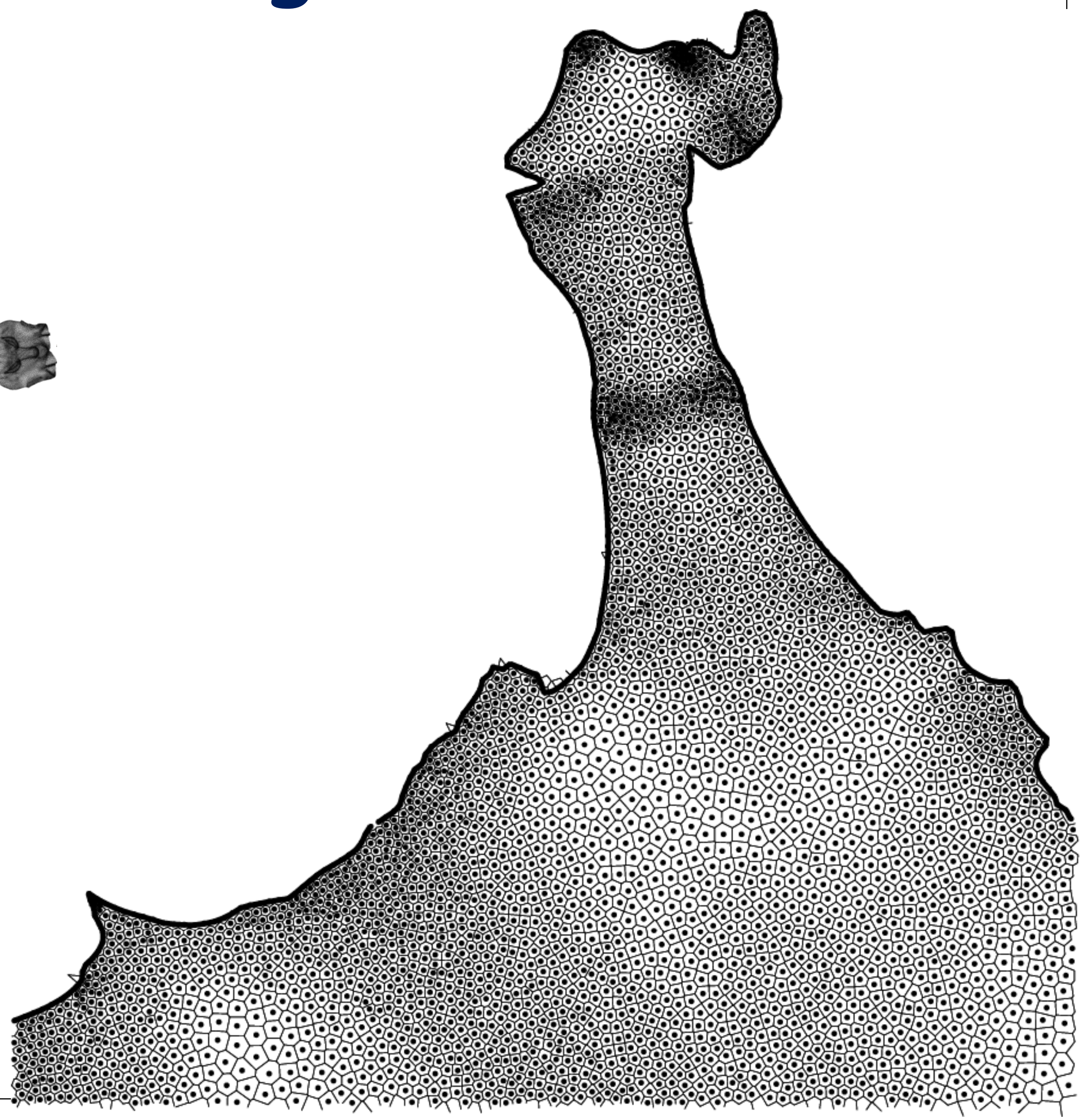


[Sheffer]

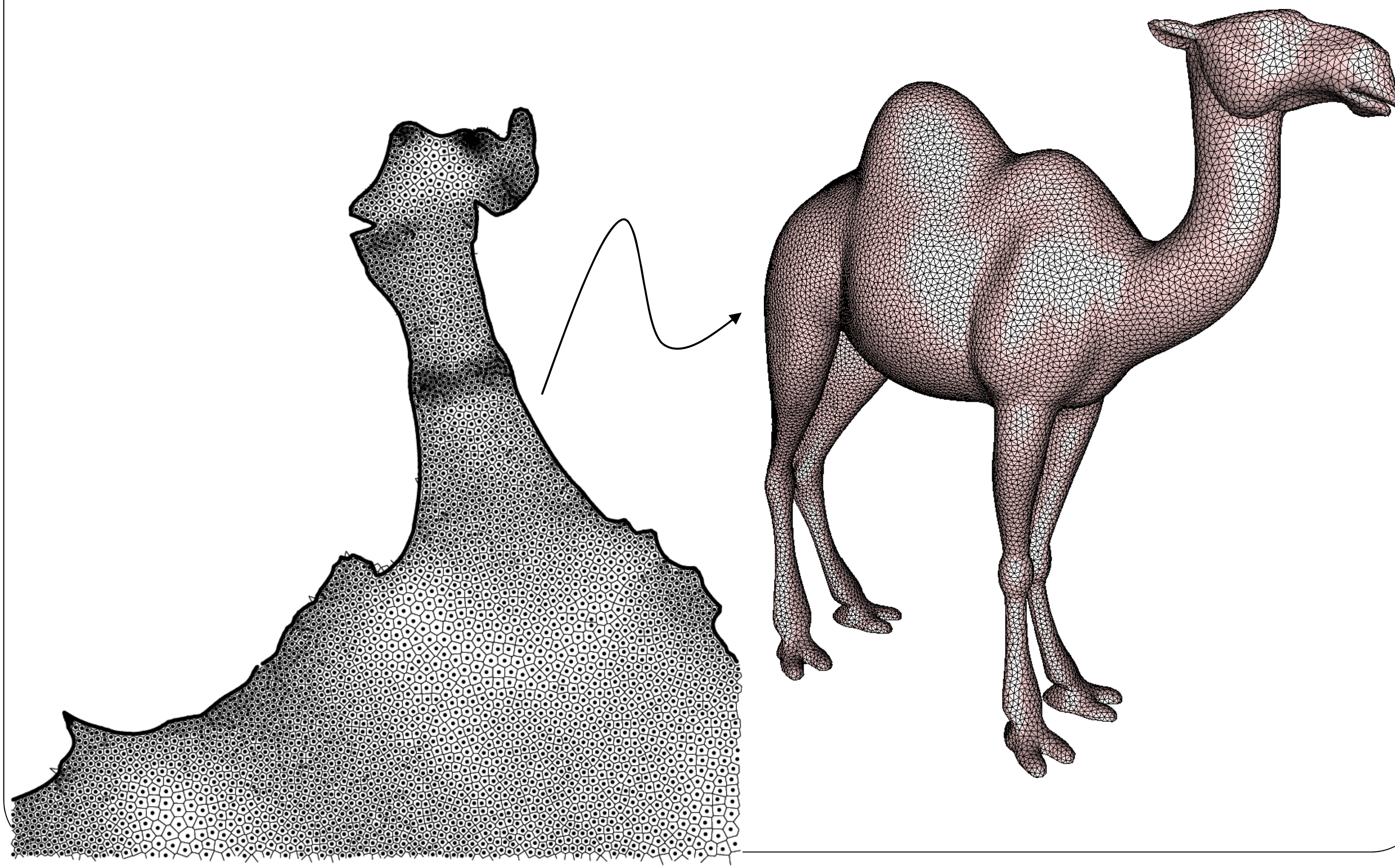


Uniform remeshing

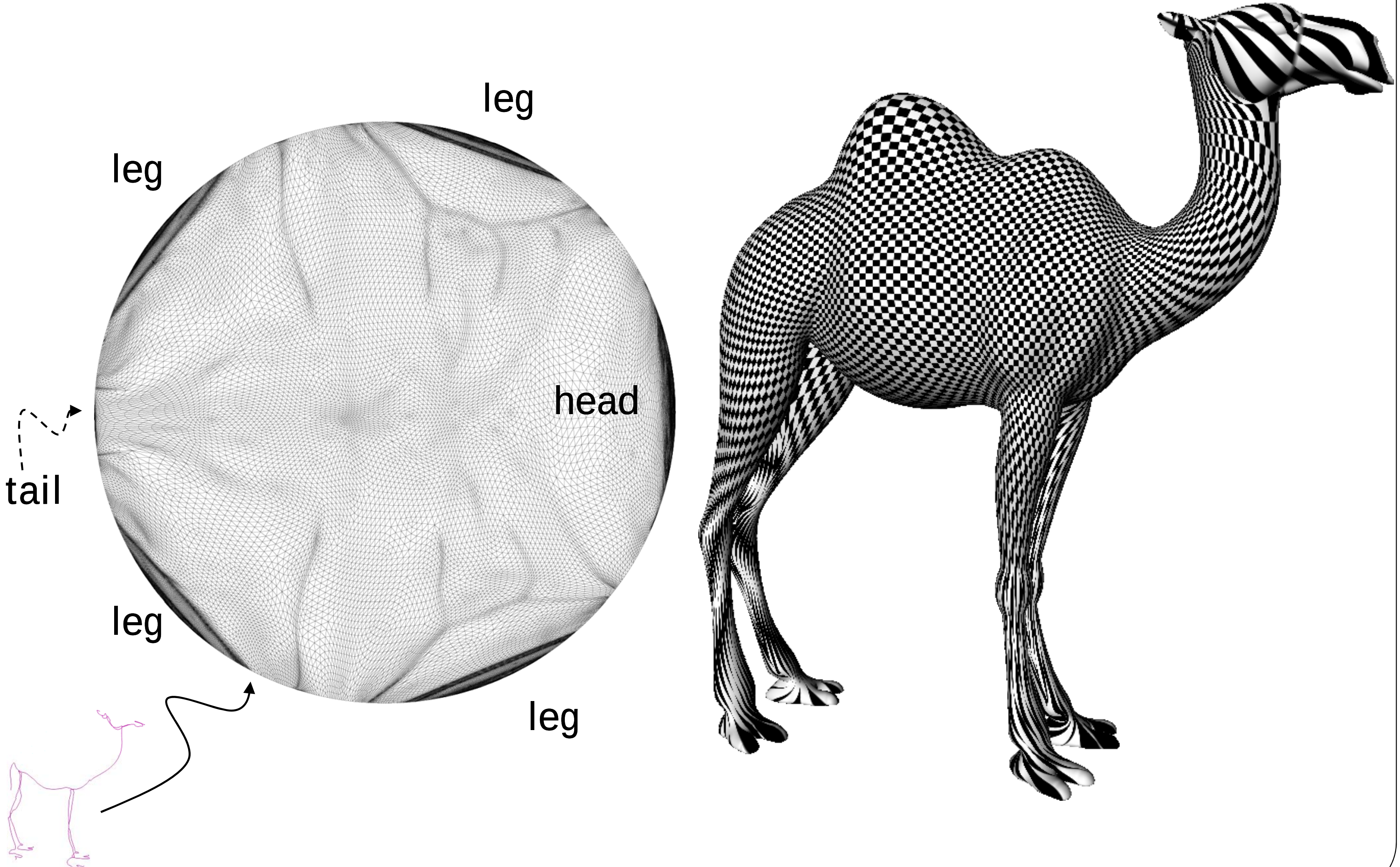




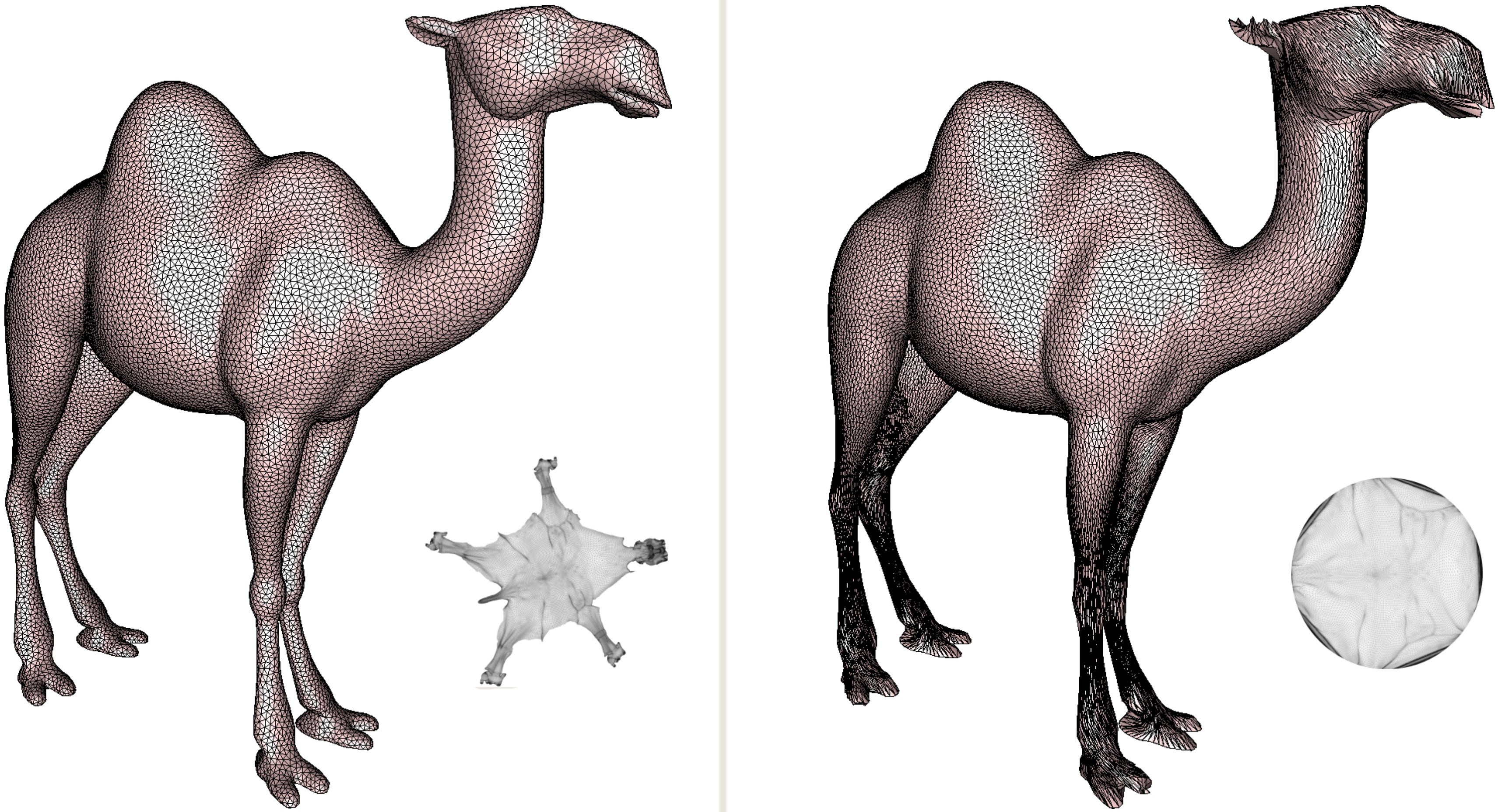
Uniform remeshing



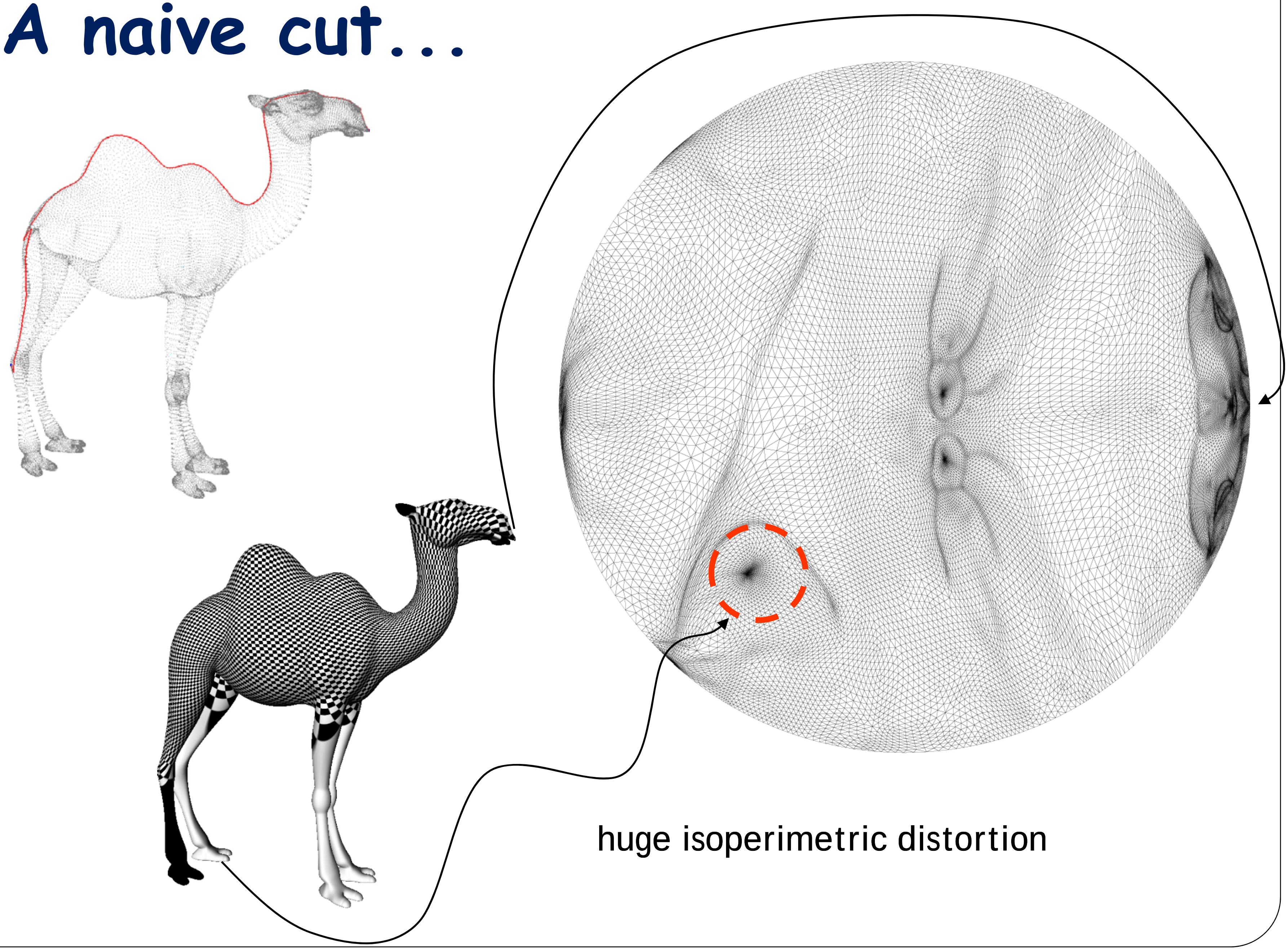
Same cut, fixed boundary ?



Remeshing with Free vs fixed boundary

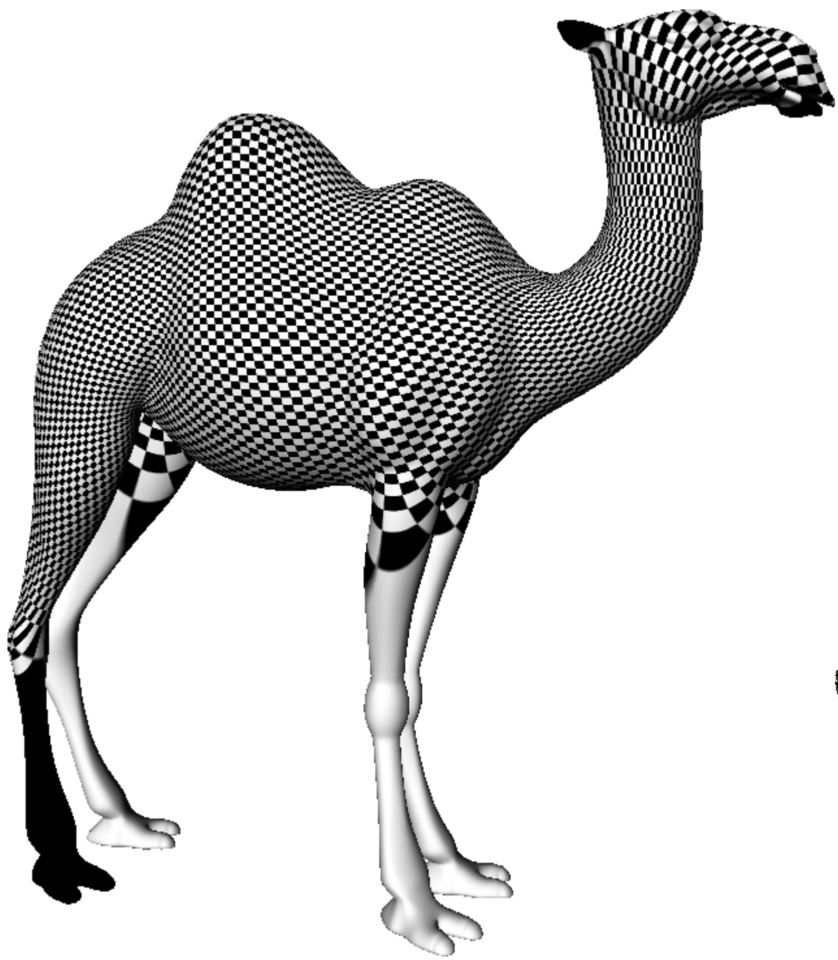


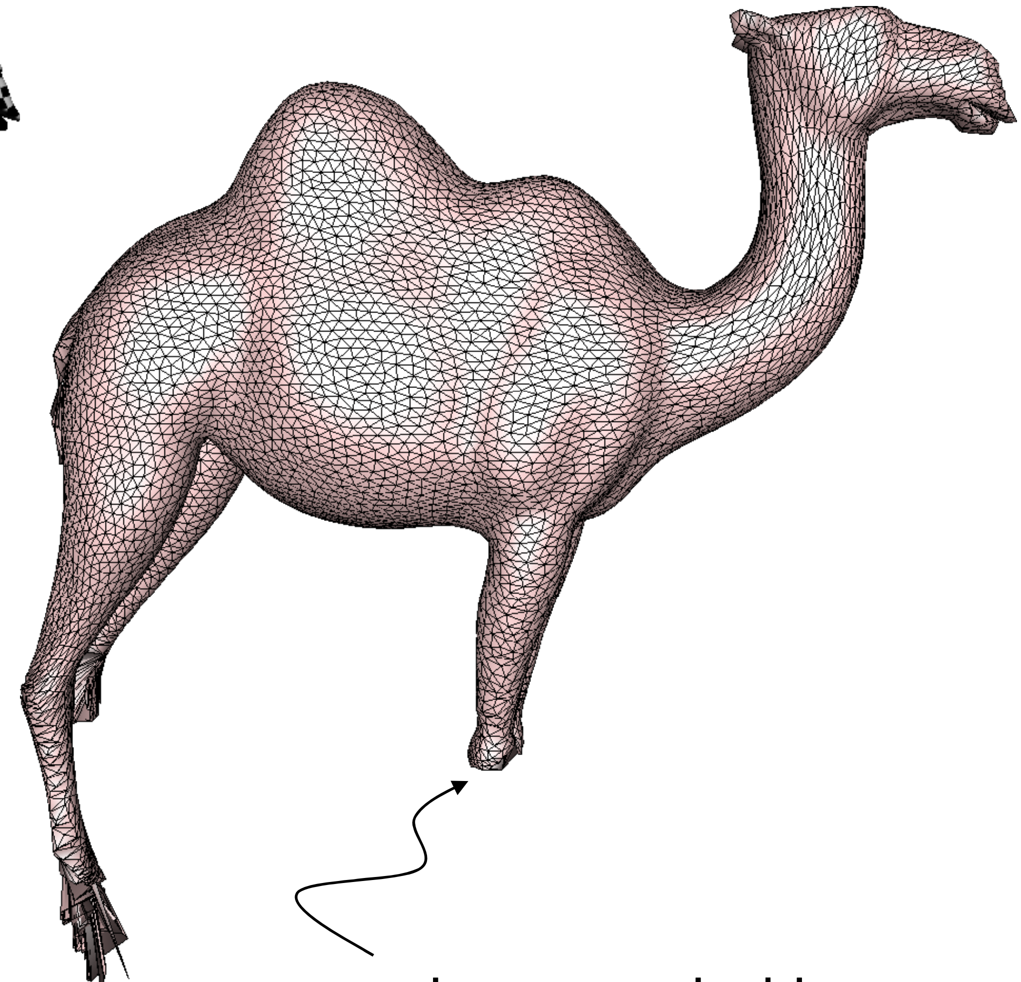
A naive cut...



huge isoperimetric distortion

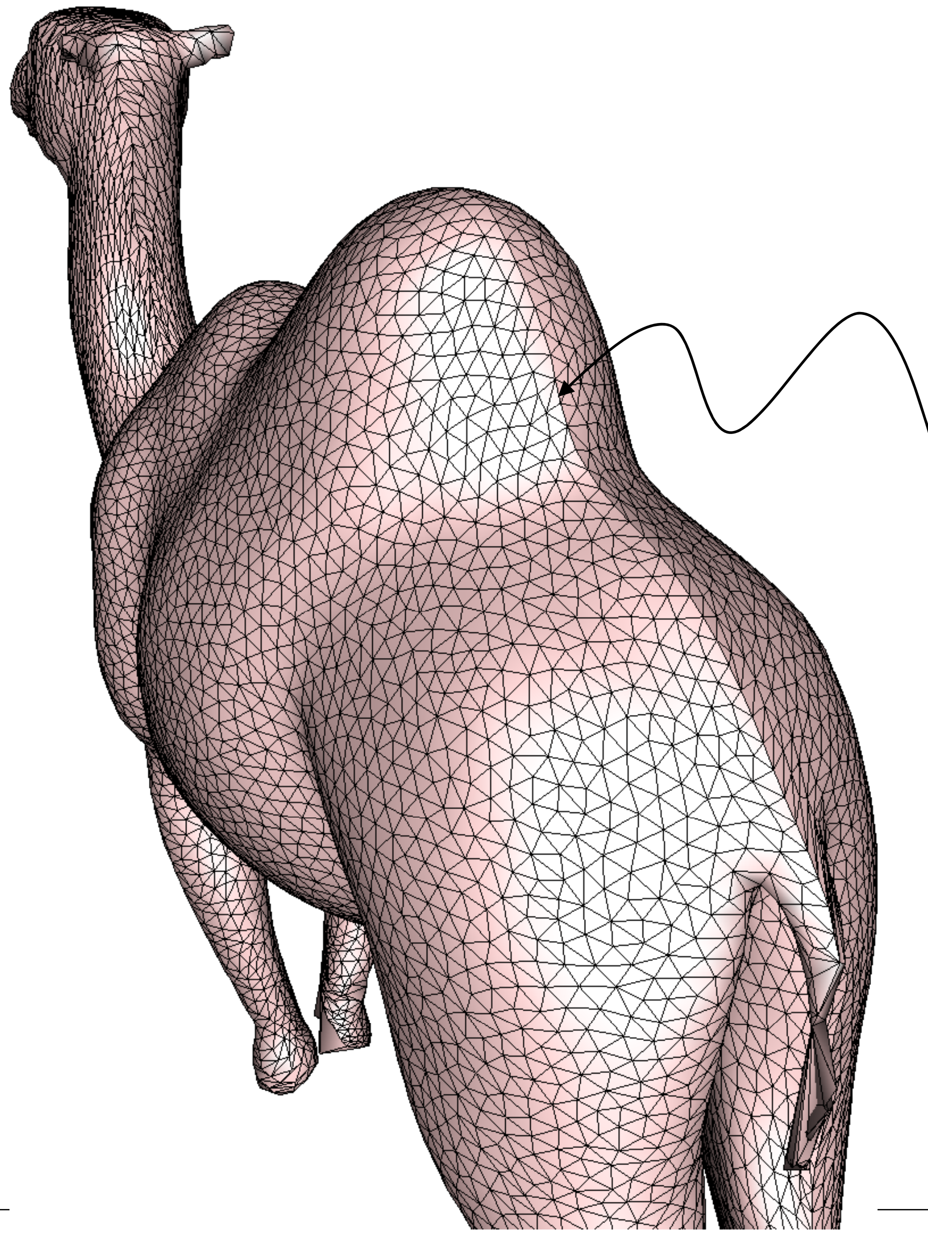
Numerical issues





serious numerical issues
with sock-like shapes

Moreover...



visible seam (cut graph has been sampled like a set of curves)

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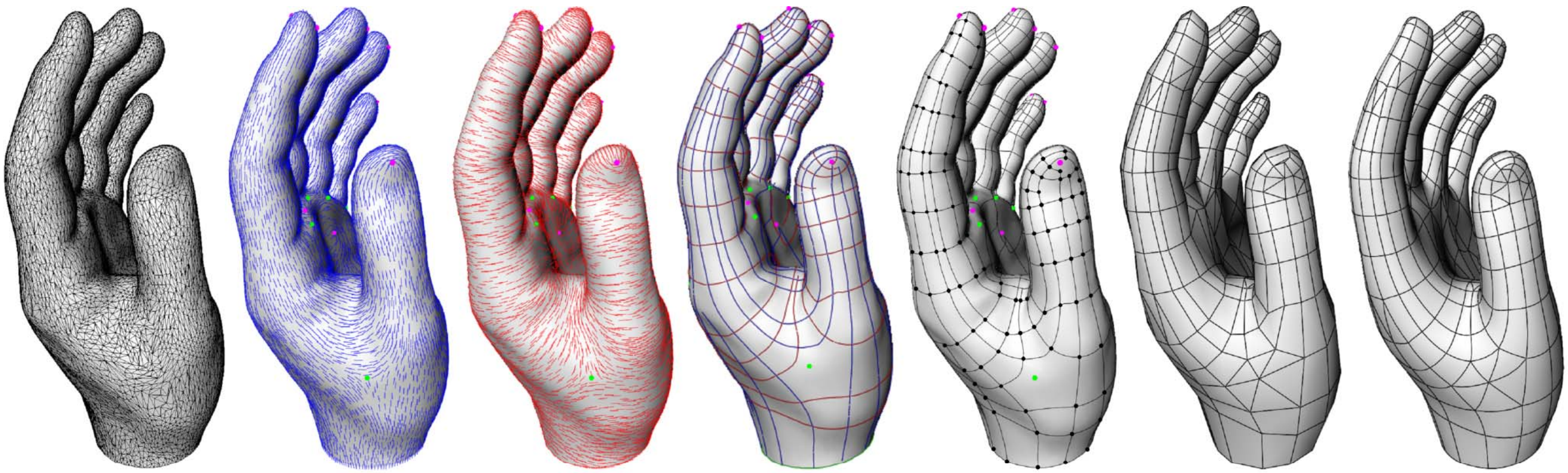
Conclusion

- Guarantee: vertex budget
- Centroidal Voronoi diagram: captures the essence of isotropic sampling
- Flexible design through density
- Handle features
- Handle important area distortion
- Still some limitations

Anisotropic Remeshing



input mesh *direction fields* *sampling* *meshing* *output mesh* *after smoothing*