Remeshing

Geometric Processing

CS 7960

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Overview

- Introduction
- Explicit Surface Remeshing
- Isotropic Surface Remeshing

Why Remeshing ?

- Unsatisfying „raw" input meshes
  - Input from Modelling, Scanning
- Improve mesh for further work
  - Transmission
  - Compression / Storing
  - Modelling
  - Rendering
  - Calculations (eg. FE-Analysis)

Requirements

- Graphics Requirements
  - Visual Quality versus Size
  - Speed of remeshing (LOD ?)
- Engineering Requirements
  - Regular Connectivity
  - Regular Geometry

Quality Measures

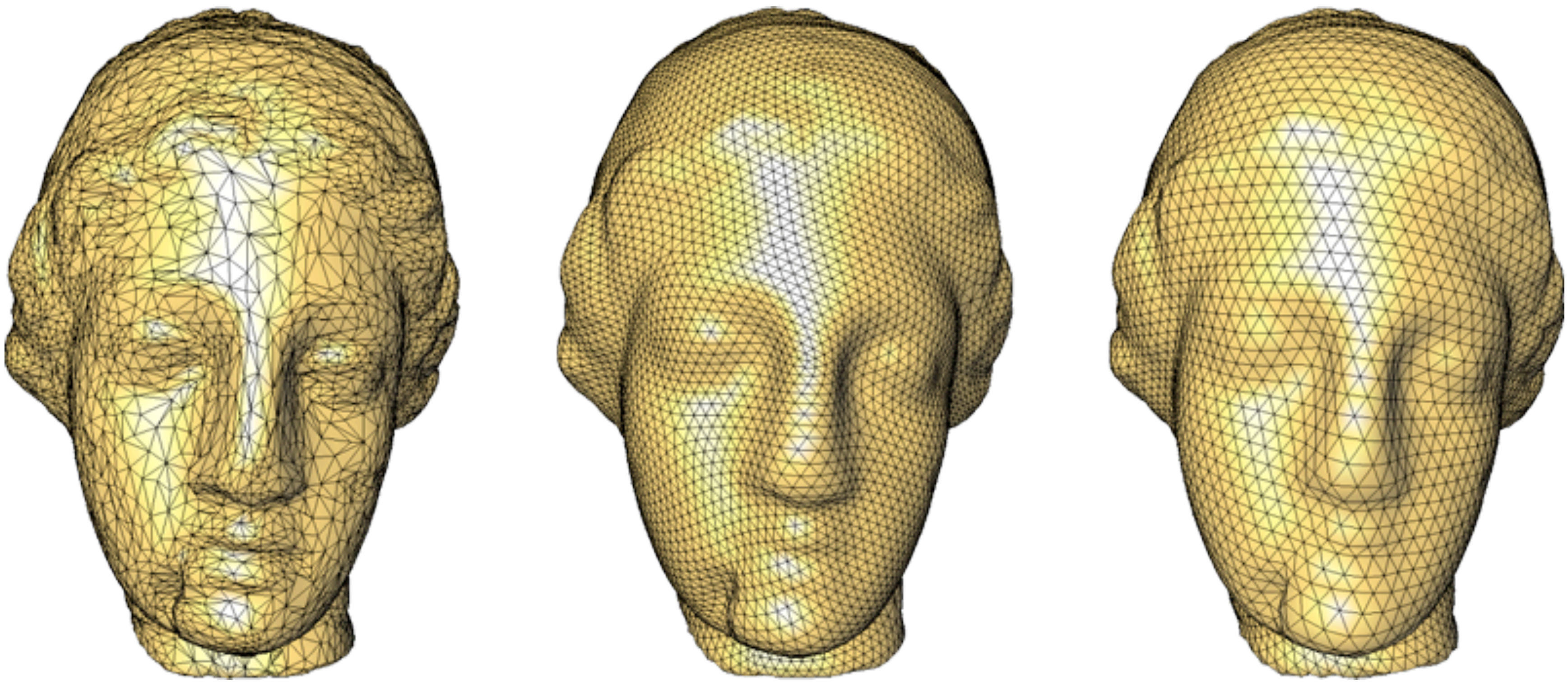
- Triangle Angles / Sizes
  - Smooth gradation of sizes
  - Uniform sizes
- Regularity
  - Vertex valence / Connectivity
  - Vertex sampling
- Mesh Size / Complexity
- Deviation from original surface
- Based on application results
  - Compression
  - Reendering Speed

Classification by Goal

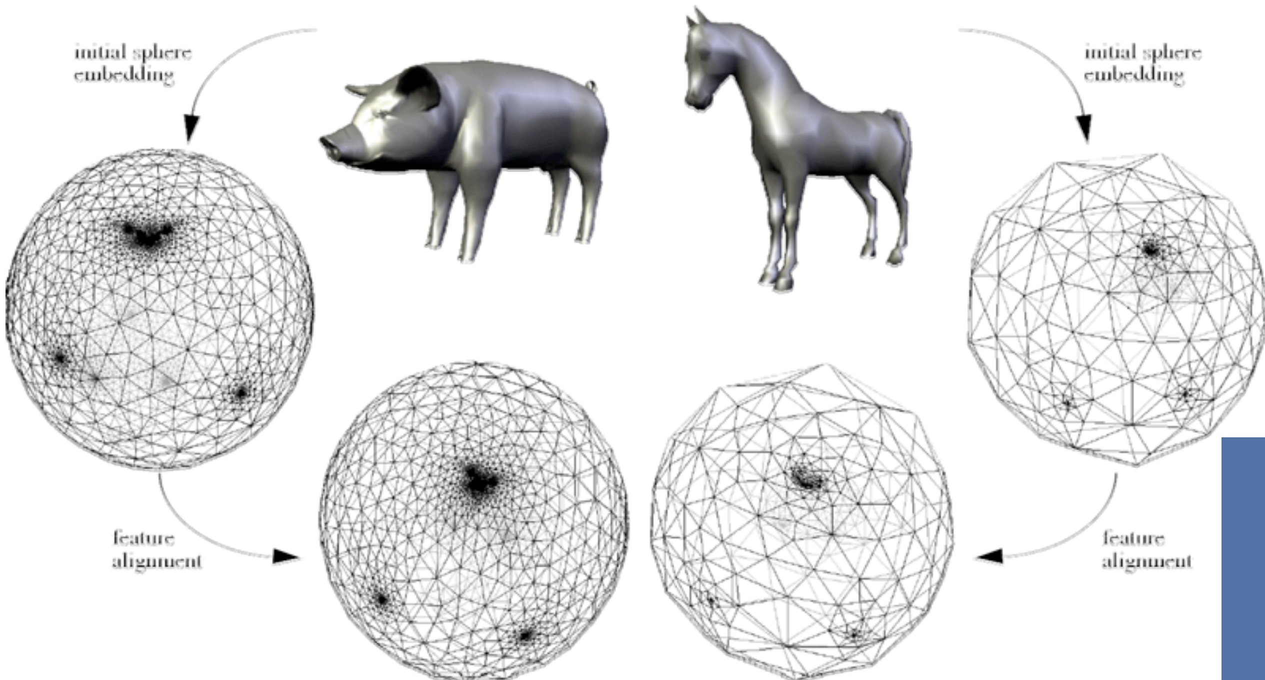
- Structured Remeshing
- Compatible Remeshing
- High Quality Remeshing
- Feature Remeshing
- Error Driven Remeshing

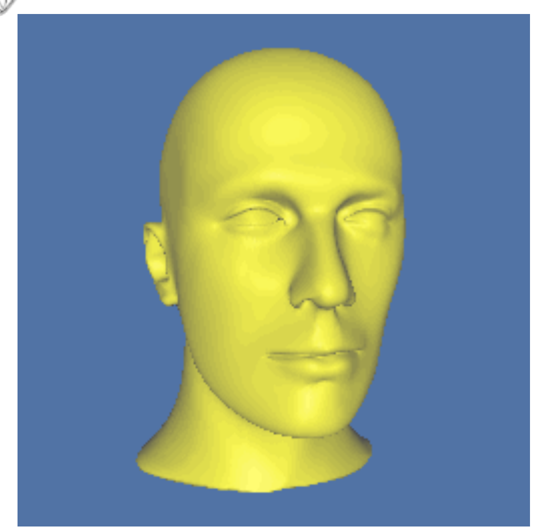
From: Recent Advances in Remeshing of Surfaces
P. Allies, G.Ucelli, C. Gotsman, M. Attene

Structured Remeshing

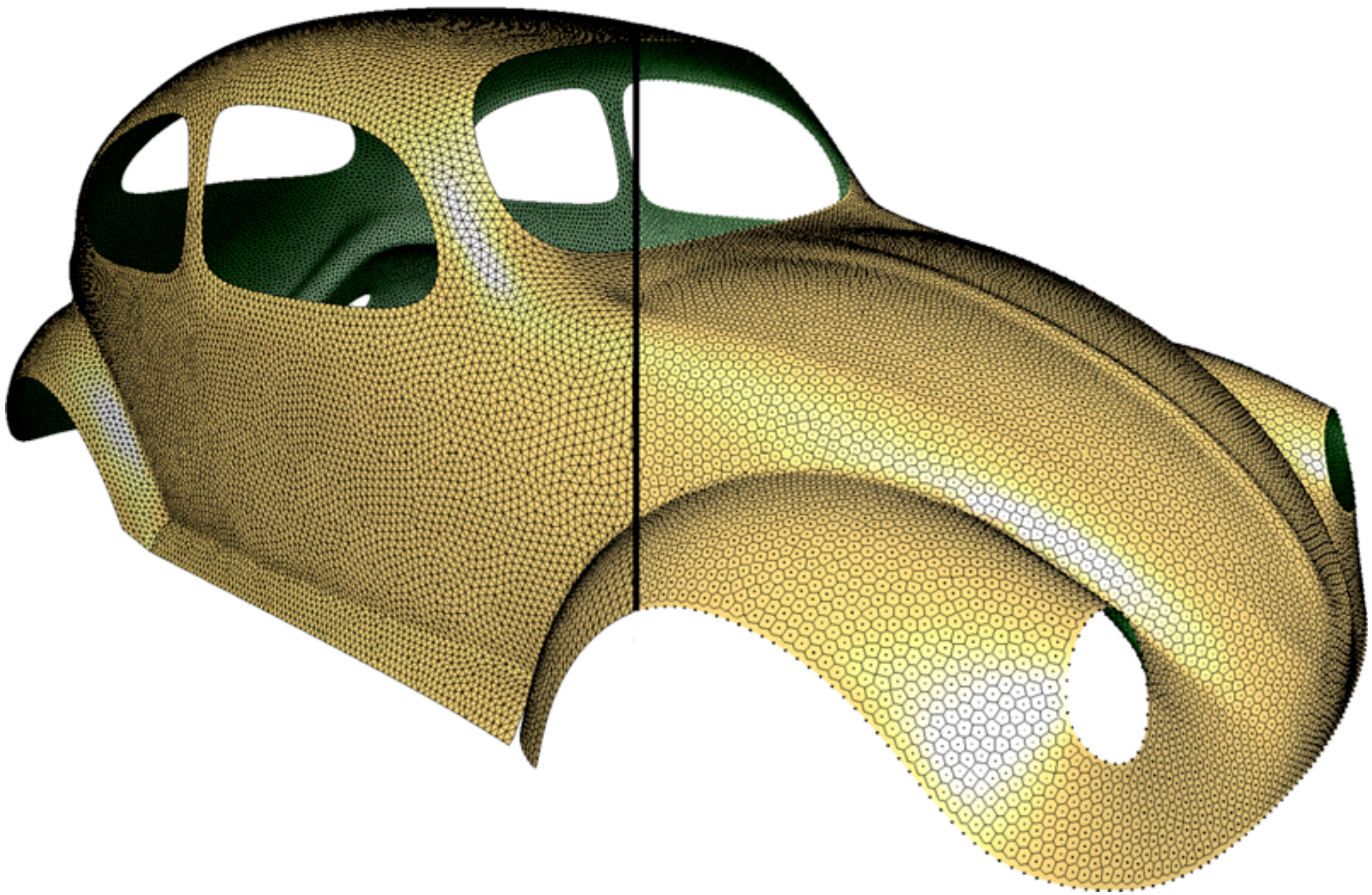


Compatible Remeshing

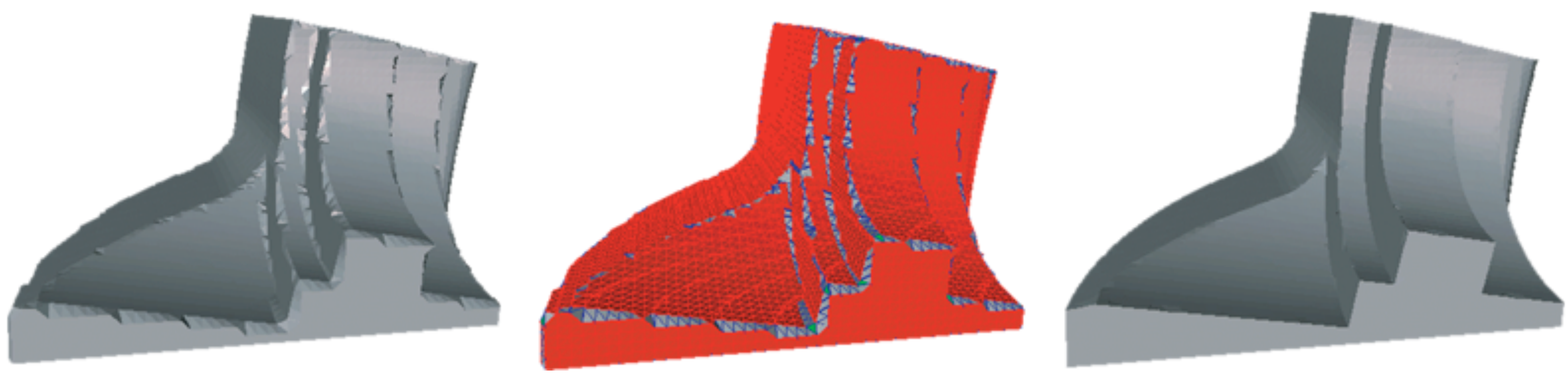




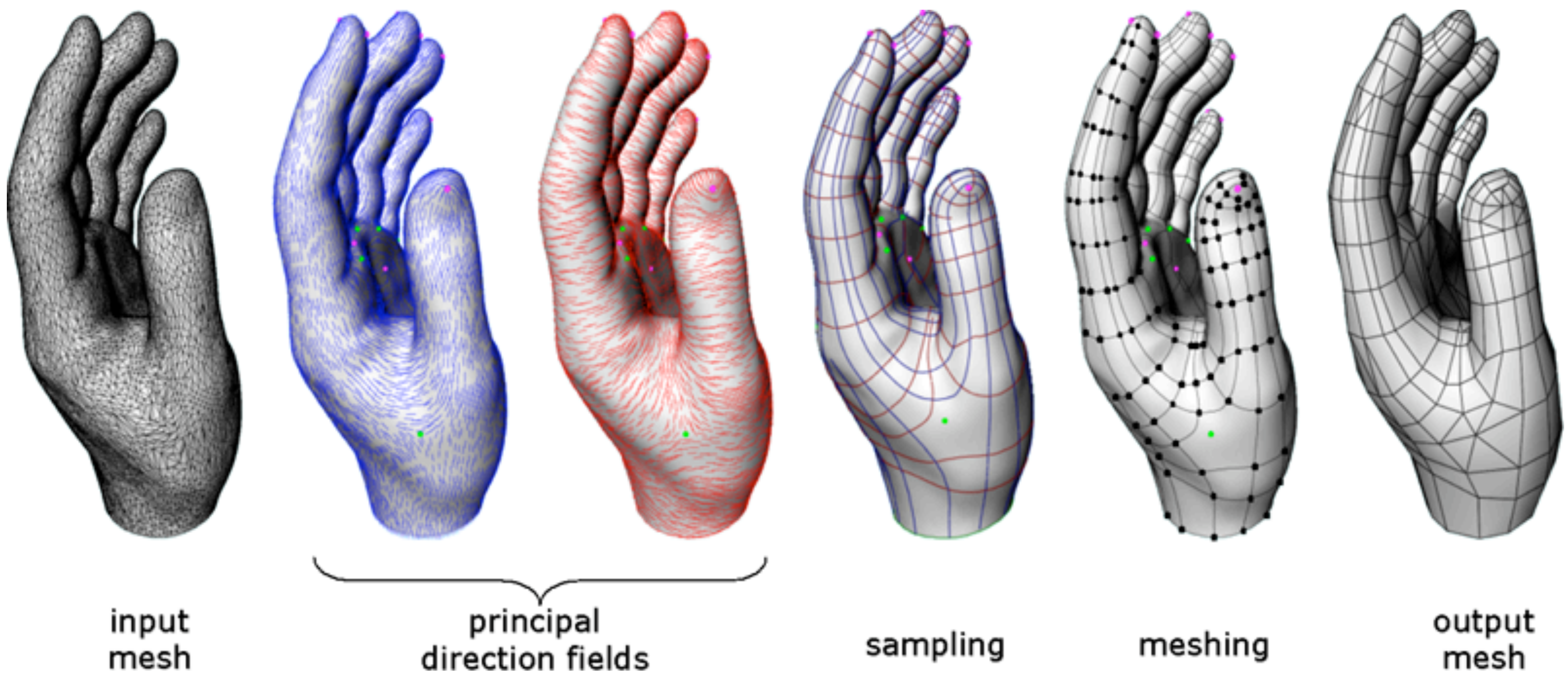
High Quality Remeshing



Feature Remeshing



Error Driven Remeshing



Classification by Technique

- Global parametrization of Mesh
  - Difficult to find Parametrization, Slow
  - Cutting of Surface maybe needed
  - Distortion
- Local modifications directly on Mesh (Mesh Adaption Process)
  - Expensive operations in 3D or less accurate in tangent plane

Overview

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Main Ideas

- Local optimizations through local parametrization
- Curvature sensitive remeshing
- Series of steps
  - Adjust number of vertices
  - Area-based remeshing
  - Regulariztion
  - Angle-based smoothing

Two meshes

- Original mesh MO
  - Surafce approximated by Bezier-patches (PN-Triangles)
  - Coordinates on surface described for each face using barycentric coordinates of the face as follows

$$b^1 = \frac{\mathcal{A}(q, q_2, q_3)}{\mathcal{A}(q_1, q_2, q_3)},\ b^2 = \frac{\mathcal{A}(q, q_3, q_1)}{\mathcal{A}(q_1, q_2, q_3)},\ b^3 = \frac{\mathcal{A}(q, q_1, q_2)}{\mathcal{A}(q_1, q_2, q_3)}$$

  - Normals on surface quadratic interpolated
- Mesh for remeshing M
  - Initialized to MO

Error Control

- Smoothness

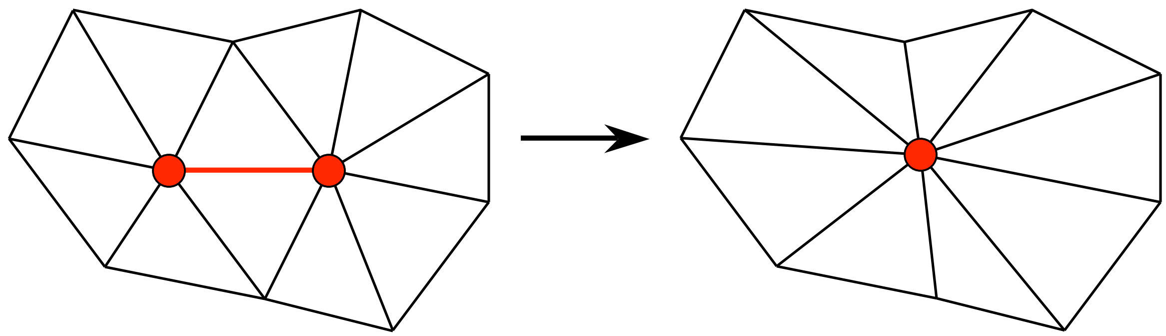
$$E_{smth}(f) = \max_{i \in \{1,2,3\}} \langle N_f, N_{v_i} \rangle < \cos \theta_{smth}.$$

- Distance between f and surface

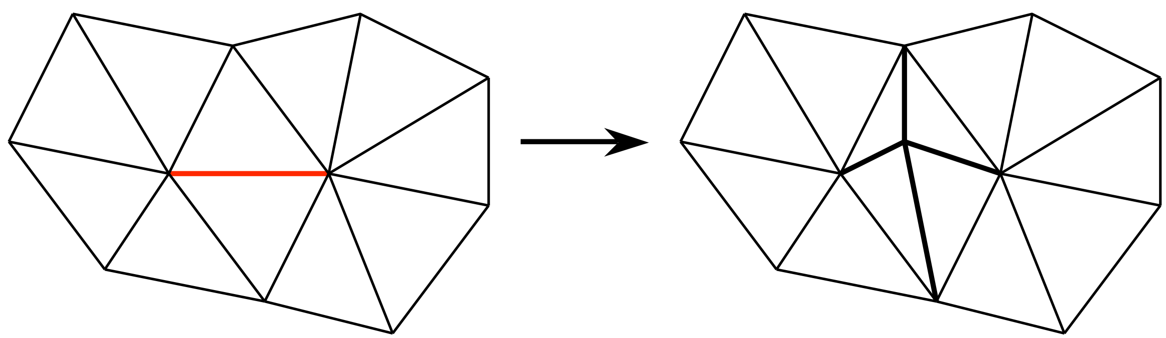
$$E_{dist}(f) = \max_{i \in \{1,2,3\}} \langle N_{v_i}, N_{v_{i+1}} \rangle < \cos \theta_{dist}.$$

Step 1: Adjusting # of Vertices

- Edge collapse

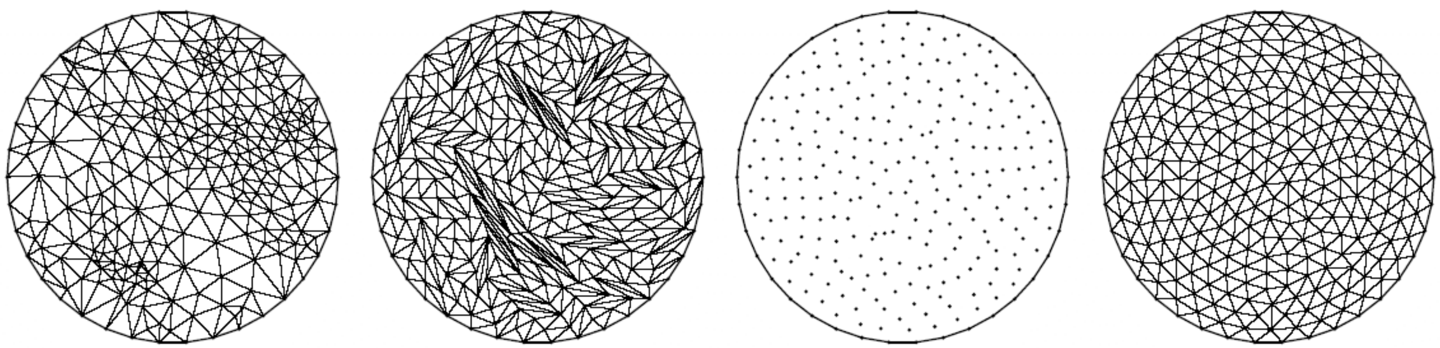


- Edge split



Step 2: Area based remeshing

- Iterations of edge flips and area based vertex-relocations



Area based vertex relocation

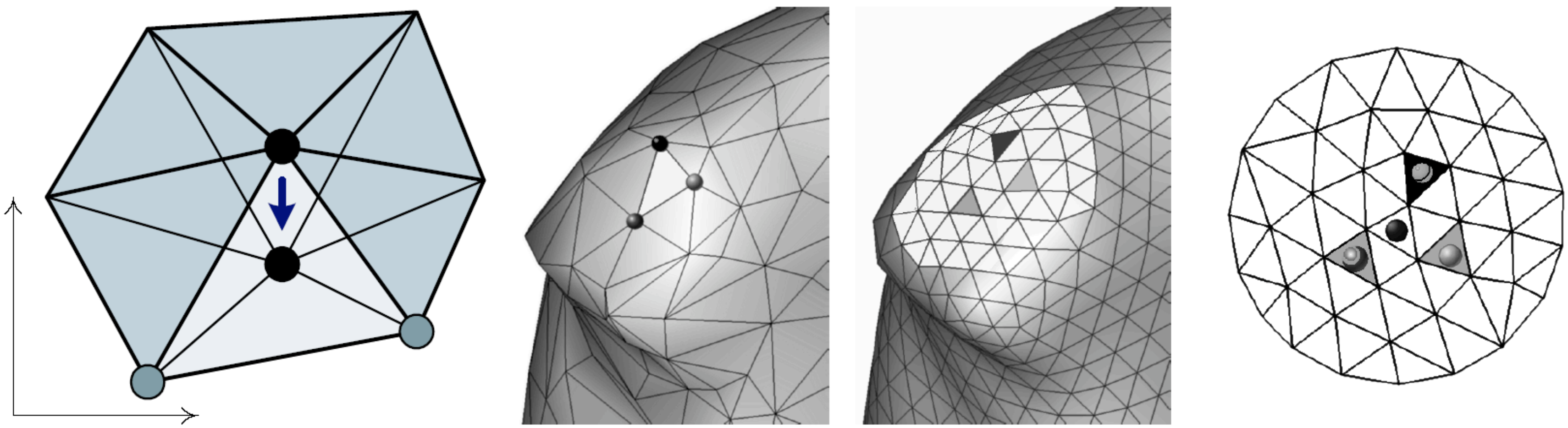
- Defintion of density function on original mesh based on curvature.

$$(x,y) = \arg\min_{(x,y)} \sum_{i=1}^{k} \left(\mathcal{A}_i(x,y) - \mu_i \mathcal{A}\right)^2$$

Vertex relocation

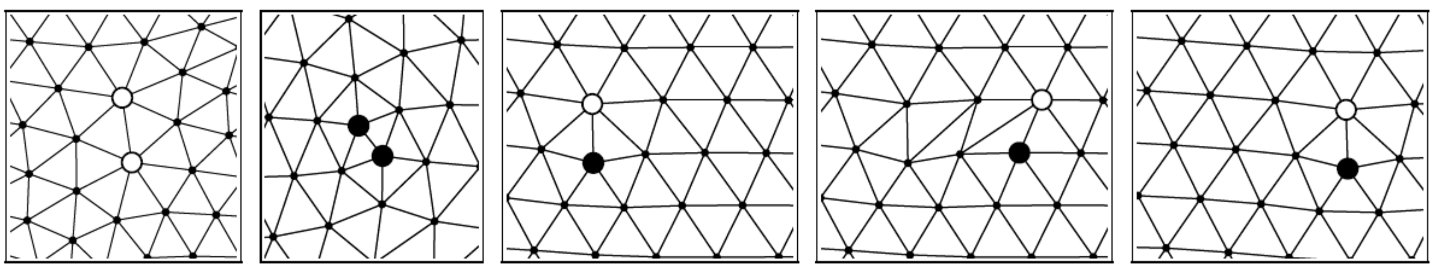
- Transform mesh locally into 2D
  - Local parametrization into geodesic polar map
  - Overlapping patches
- Relocation in parameter space
- Transform back into 3D
  - Keeping track of the position of each vertex on the original Surface using patchwise parametrization of original mesh.

Patchwise Parametrization



Step 3: Connectivity regularization

- Classifaction of edges
  - Long
  - Short
  - Drifting



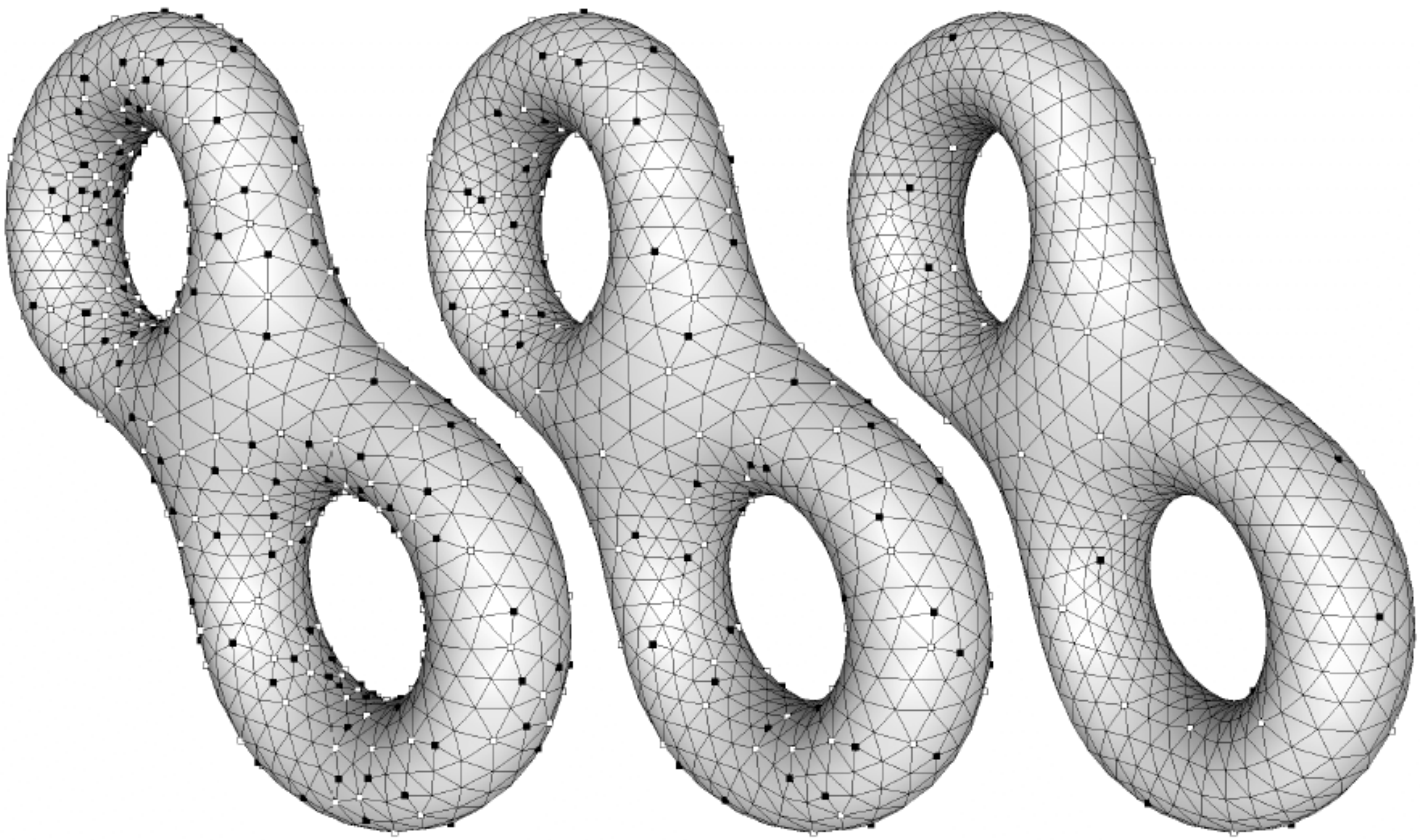
Operations on edges

- Long edges
  - Refinement
- Short edges
  - Collapse edge
- Drifting edges
  - Moving through edge flips

Procedure

- Priority queue (Easy edges before drifting)
- Remove easy edges
- Move drifting each to create an easy edge with other irregular vertices
- Stop when no drifting edges are left.
- Local angle based smoothing after each modification

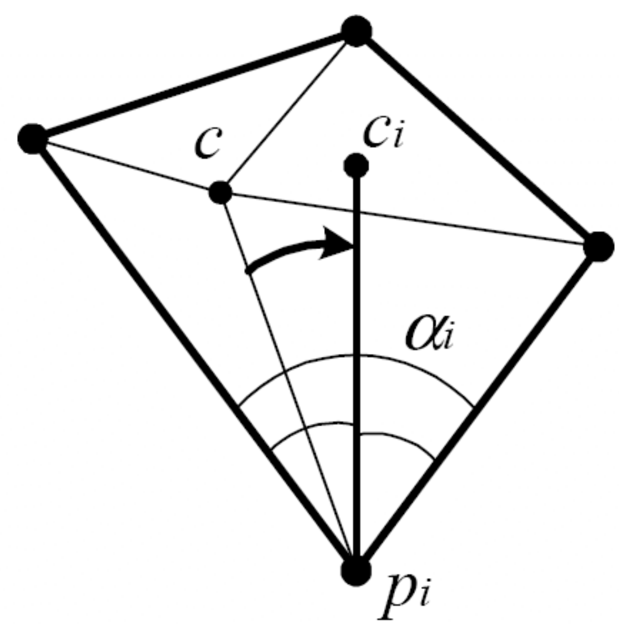
Regularization results



Step 4: Angle Based Smoothing

- Weighted angle – based smoothing in parameter space
  - High Quality Compatible Triangulations
    Vitaly Surazhsky Craig Gotsman
    http://www.imr.sandia.gov/papers/imr11/surazhsky.pdf

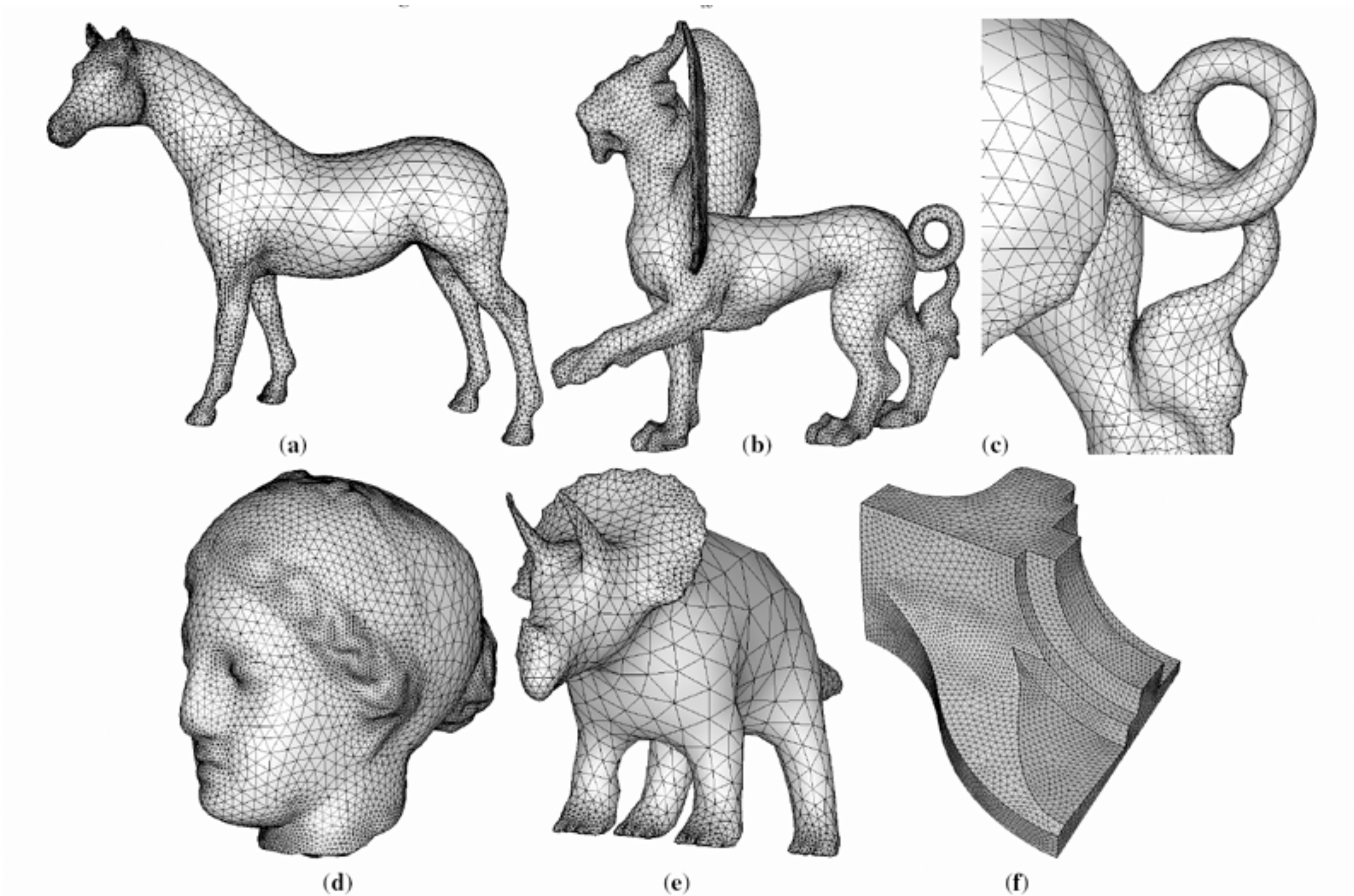
$$c_{new} = \frac{1}{\sum_{i=1}^{k} 1/\alpha_i^2} \cdot \sum_{i=1}^{k} \frac{1}{\alpha_i^2} \cdot c_i$$



Results

Model	Vertices	Irreg (%)	Min∠ (deg)	Ave∠ (deg)	Error (10^{-3})	Time (sec)	TG (kB)	Conn (bpv)	Geom (bpv)
Venus (original)	8,268	74.9	0.25°	34.7°	—	—	23.9	2.83	20.9
Venus (uniform)	9,240	4.4	25.8°	53.3°	3.5	15.4	15.3	0.47	13.1
Venus (non-uniform)	8,705	6.7	25.9°	52.4°	2.7	16.5	17.4	0.72	14.8
Cow (original)	2,904	38.1	2.8°	30.1°	—	—	7.89	1.89	20.4
Cow (a)	4,551	9.5	8.1°	48.8°	5.8	8.2	8.95	0.93	15.2
Cow (b)	4,984	10.2	12.5°	49.6°	5.0	8.9	9.67	0.95	14.9
Cow (c)	5,249	10.3	11.1°	49.2°	4.8	9.3	11.3	0.94	14.0
Feline (original)	49,864	63.8	3.8°	40.0°	—	—	100	2.38	14.2
Feline	10,825	13.8	7.4°	48.3°	6.4	74	21.3	1.09	15.1
Horse (original)	19,851	64.5	1.7°	35.9°	—	—	46.0	2.34	16.6
Horse	5,695	10.3	9.1°	50.1°	6.1	28.4	11.0	0.97	14.8
Triceratops (original)	2,832	59.3	0.02°	29.6°	—	—	7.68	2.17	20.0
Triceratops	2,758	13.3	5.6°	42.2°	8.4	12.3	5.93	1.2	16.4
Fan disk (original)	5,051	20.6	16.8°	43.0°	—	—	9.12	1.03	13.7
Fan disk	5,135	8.43	16.8°	49.1°	0.4	17.3	9.03	0.58	13.8
Helmet (original)	496	63.9	2.33°	34.5°	—	—	2.12	2.94	32.1
Helmet	2,728	6.08	14.8°	47.8°	8.9	17.7	5.46	0.67	15.7

Results



Overview

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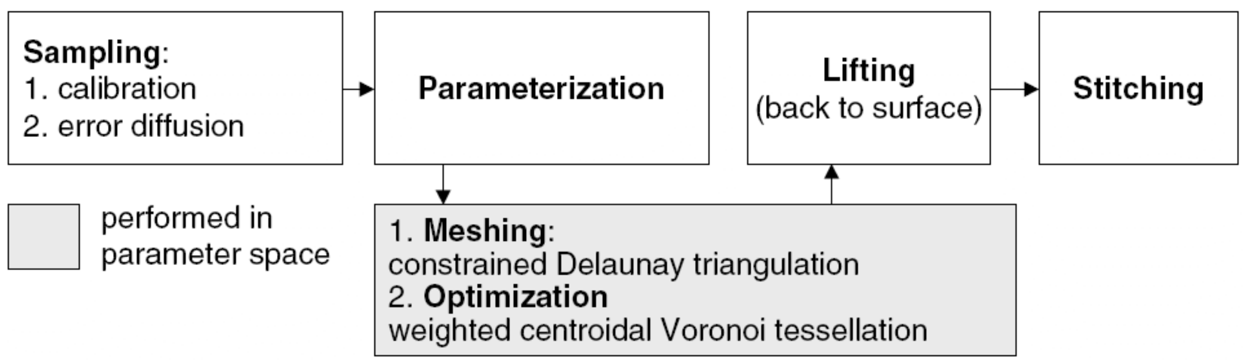
- Isotropic Surface Remeshing

Main Ideas

- Sampling of vertices using Error Diffusion directly on Mesh
- Global Parametrization
- Meshing in parameter space

Algorithm Overview

1. Callibration of Sampling
2. Sampling using Error Diffusion
3. Global Parametrization
4. Meshing
5. Lifting and Stitching



Input

- Mesh
- Feature Edges
  – Extracted from Mesh
  – Sharp Edges, Boundary Edges, Cut Edges
- Density Function for Mesh and Features
  – User given or from Geometric Properties of Mesh

Step 1: Calibration

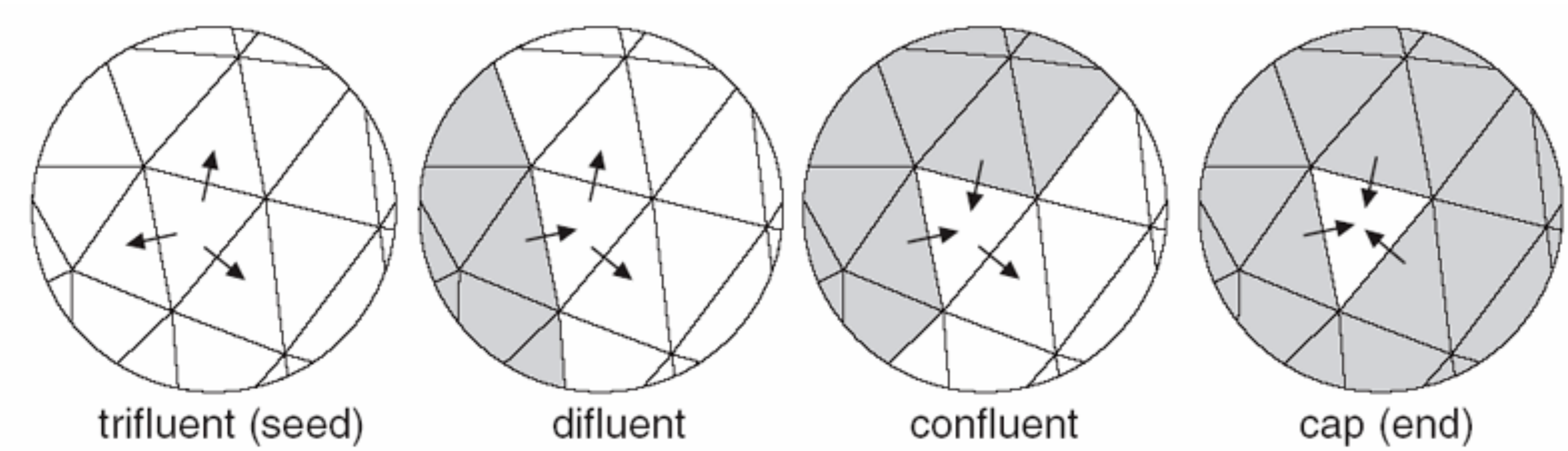
- Calculation of number of samples per density unit
- Summing of density functions over surface / features

Step 2: Vertex Sampling

- Error Diffusion over Triangles and Features

Diffusion over Triangles

- Find a processing path
  - Organize a fluency on mesh triangles



Diffusion over Triangles

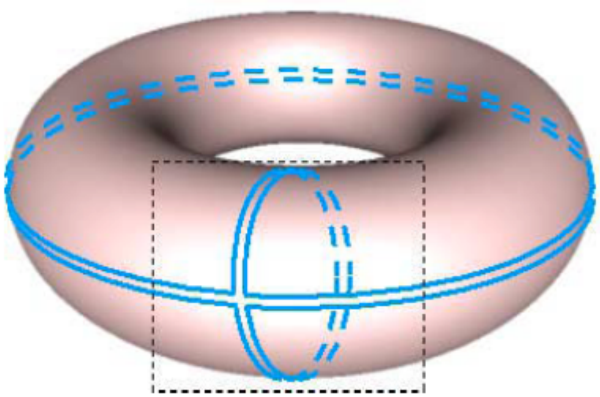
- For each Face f on the path
  - Read density amount for f
  - Deduce number of samples rounded to nearest Integer
  - Distribute error over neighboring unprocessed faces

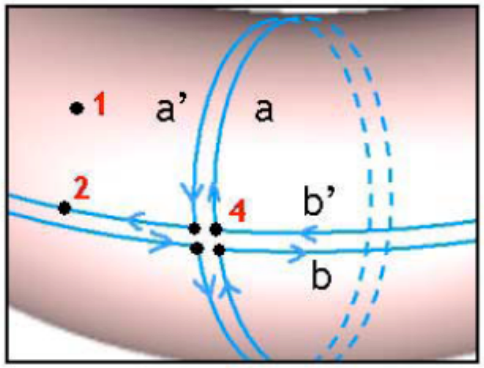
Diffusion over Features

- Go along feature edges
  - Read density amount for current edge
  - Deduce number of samples by calculating density amount over sampling rate rounded to nearest integer
  - Transport error onto next edge if last edge of current feature transport error to next feature

Step 3: Parametrization

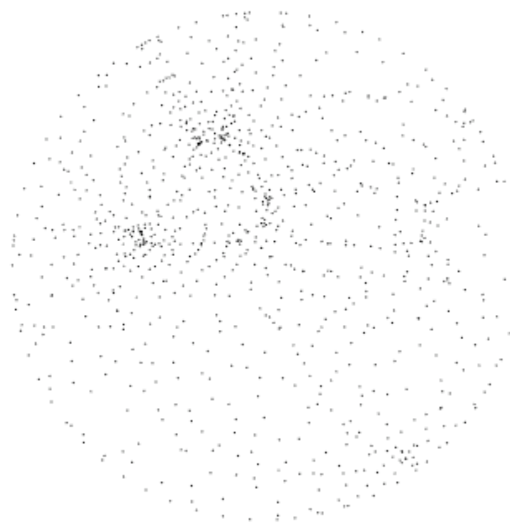
- Conformal mapping into 2D
  - Angle preserving
  - Locally isotropic
- Cuts needed for closed surfaces or genus > 0
  - Before sampling -> cuts are feature edges

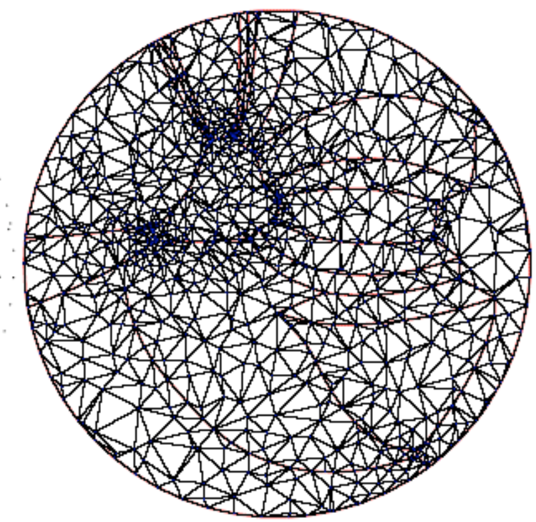




Step 4: Meshing

- Delaunay Triangulation in parameter space

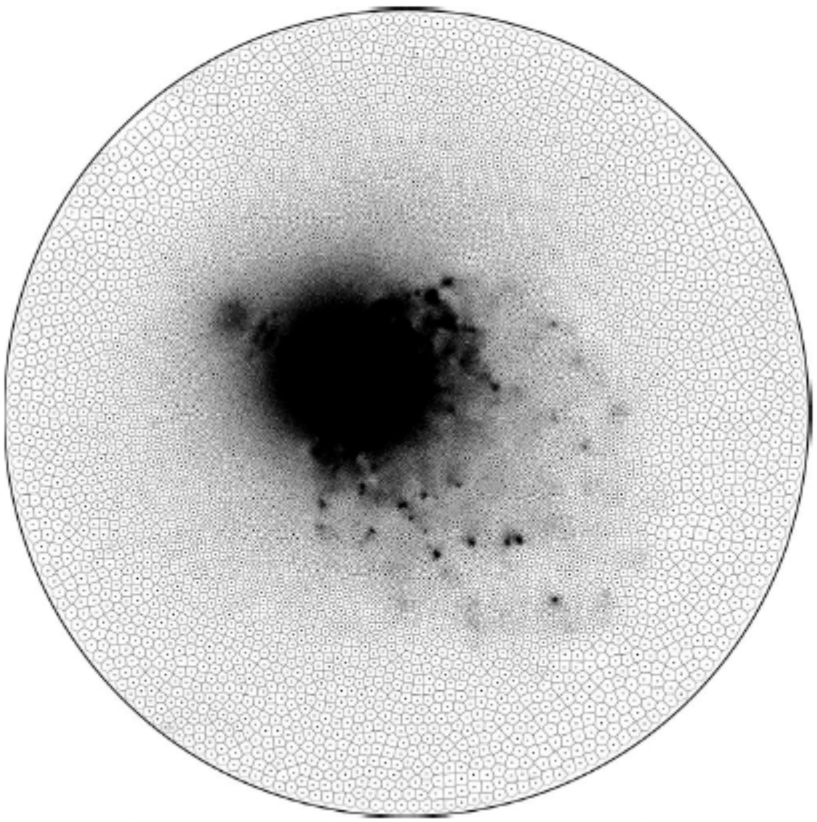


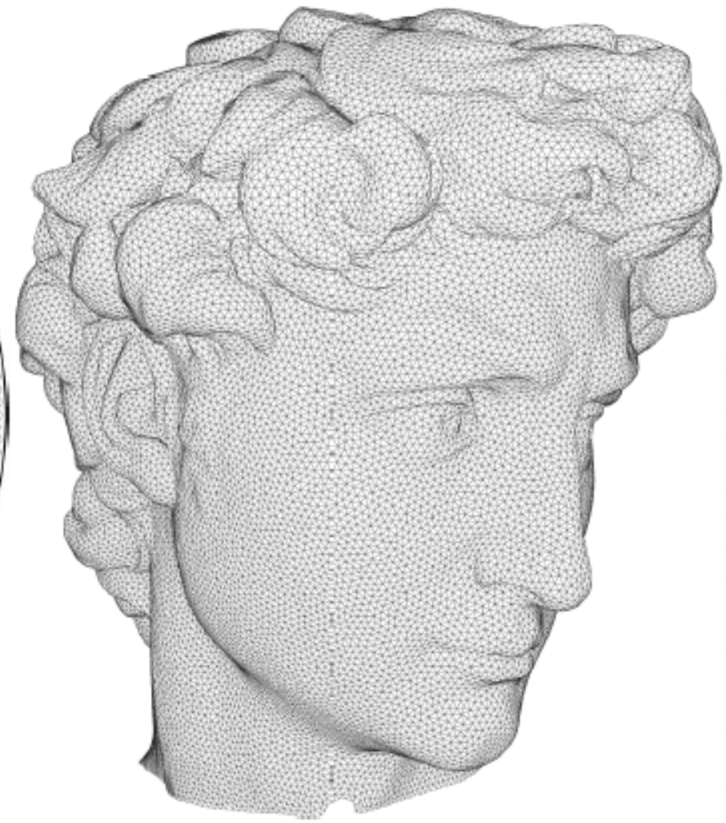


- Weighted Centeroidal Voronoi Tesselation

Weighted Voronoi Tesselation

- Centeroids evaluated using the density function
- Transformation of density function in parameter space using a stretching factor
- Lloyd relaxation
  - Voronoi tesselation
  - Compute ceneteroids

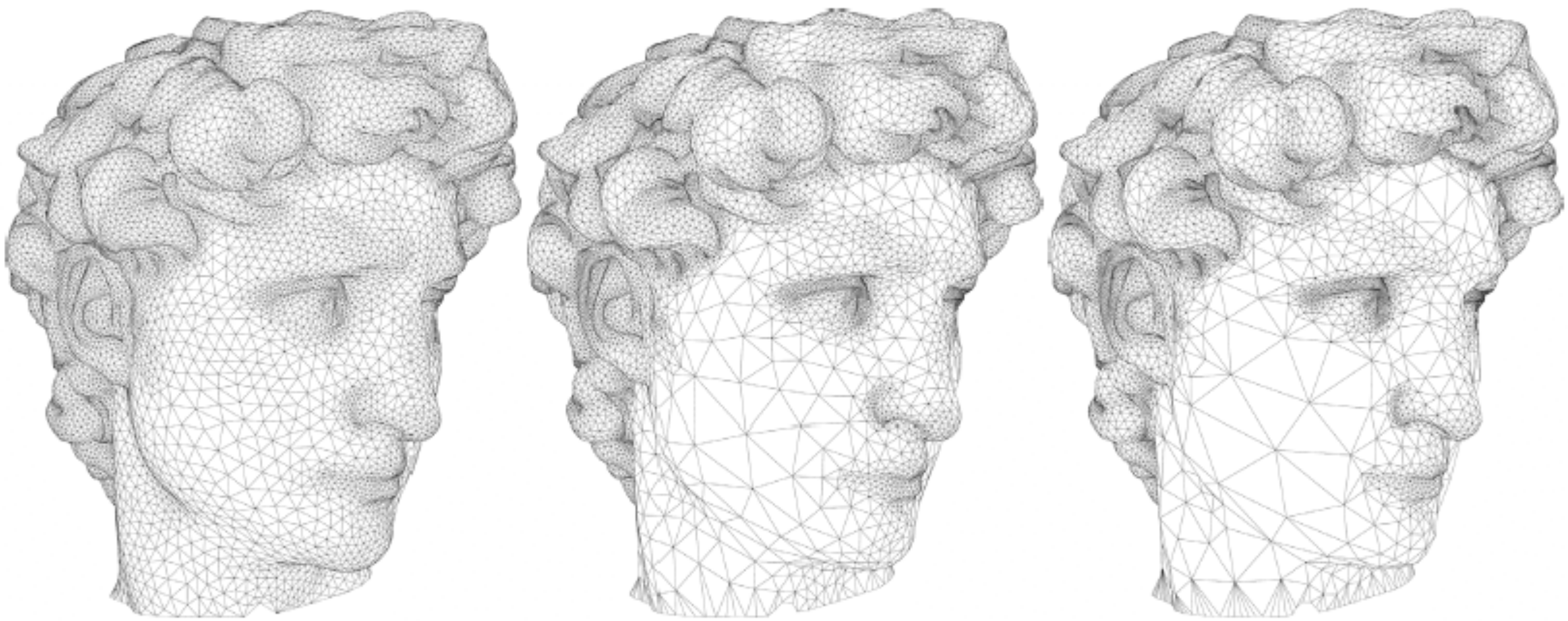




Step 5: Lifting & Stitching

- Lifting
  - Transformation of vertices in parameter space into locations on Mesh
- Stitching
  - Vertices on cut edges are merged.

Results



Results