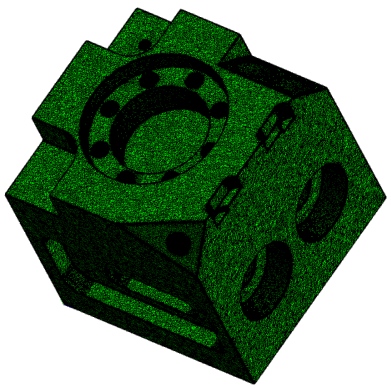
Digitized 3D mesh segmentation based on curvature analysis

S. Gauthier[1,2] **R. Bénière**[2] **W. Puech**[1] **G. Subsol**[1]



[1]LIRMM, CNRS, University of Montpellier, France
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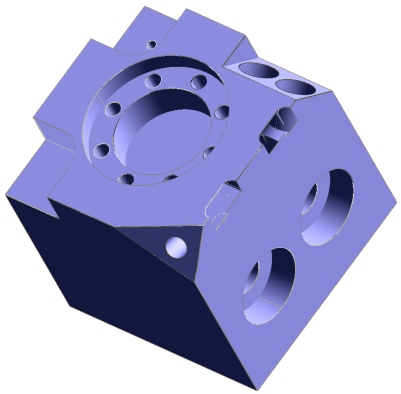


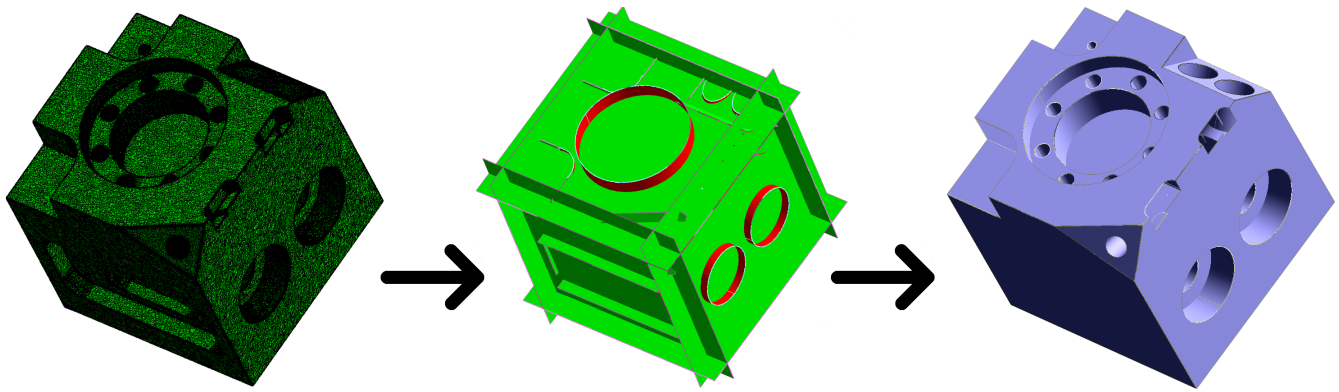
February 02, 2017

Context

Reverse Engineering

Study of an object to determine its functioning or manufacturing method.

$\Rightarrow$ Reconstruction of a 3D parametric model (combination of geometric primitives) from a discrete one (3D mesh).



Mesh **Primitives** **Parametric model**

R. Bénière, G. Subsol, G. Gesquière, F. Le Breton, and W. Puech. A comprehensive process of reverse engineering from 3D meshes to CAD models. Computer-Aided Design, 45(11), 2013.

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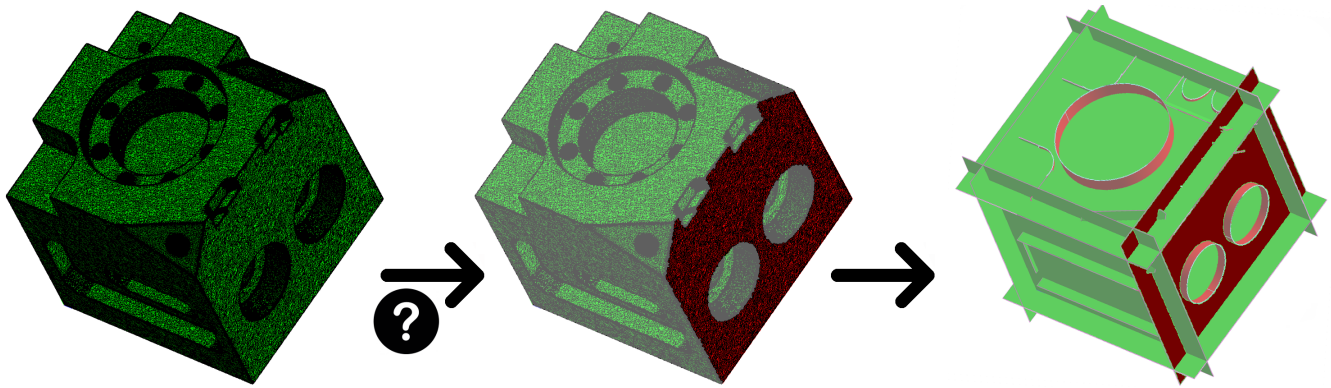
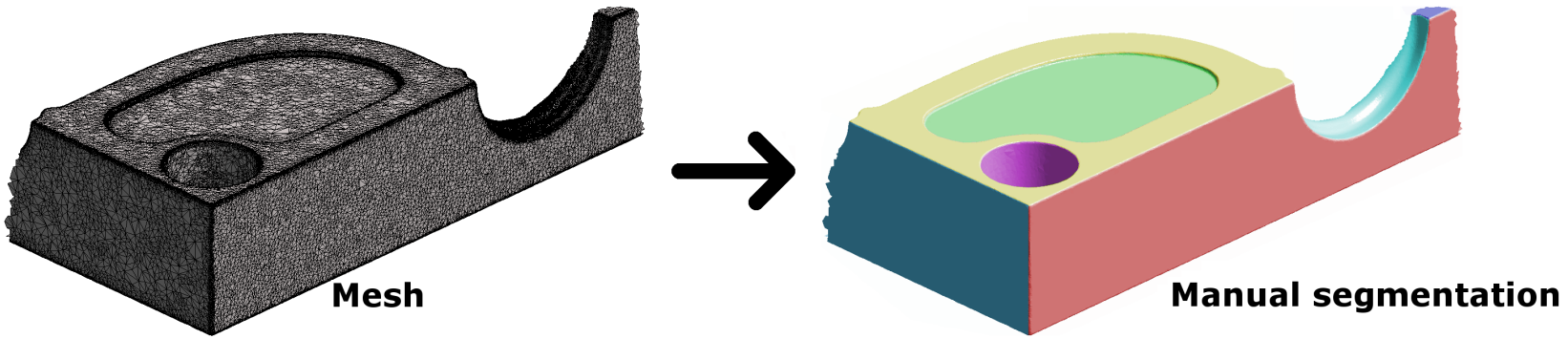


- **Problem:** how to define precisely primitive regions?

R. Bénière, G. Subsol, G. Gesquière, F. Le Breton, and W. Puech. A comprehensive process of reverse engineering from 3D meshes to CAD models. Computer-Aided Design, 45(11), 2013.

Segmentation

- **Solution:** segment the 3D mesh in homogeneous regions corresponding to the primitives.



Segmentation

Many methods exist but not efficient enough for our application.

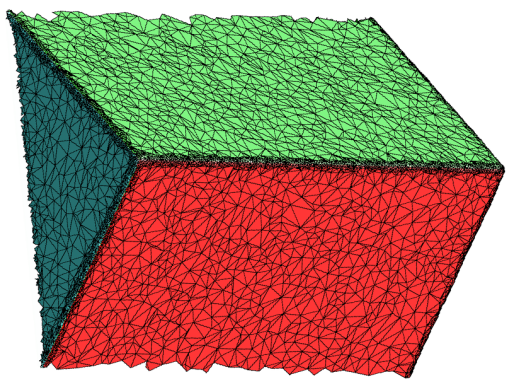
A. Shamir. A survey on mesh segmentation techniques. Computer Graphics Forum, 27(6):1539-1556, 2008.

Segmentation

Primitives are separated by “edges”.

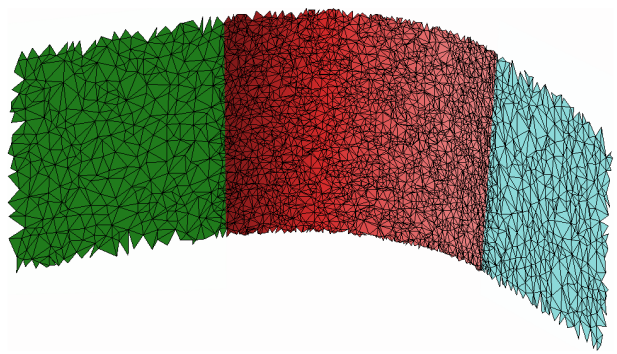
- **Idea:** Extract object edges to delimit homogeneous regions by a method based on surface curvature (k_1, k_2, k_g, k_m).

“Sharp” edges



Curvature discontinuity

“Smooth” edges



Curvature continuity

G. Lavoué, F. Dupont, and A. Baskurt. A new CAD mesh segmentation method, based on curvature tensor analysis. Computer-Aided Design, 37: 975-987, 2004.

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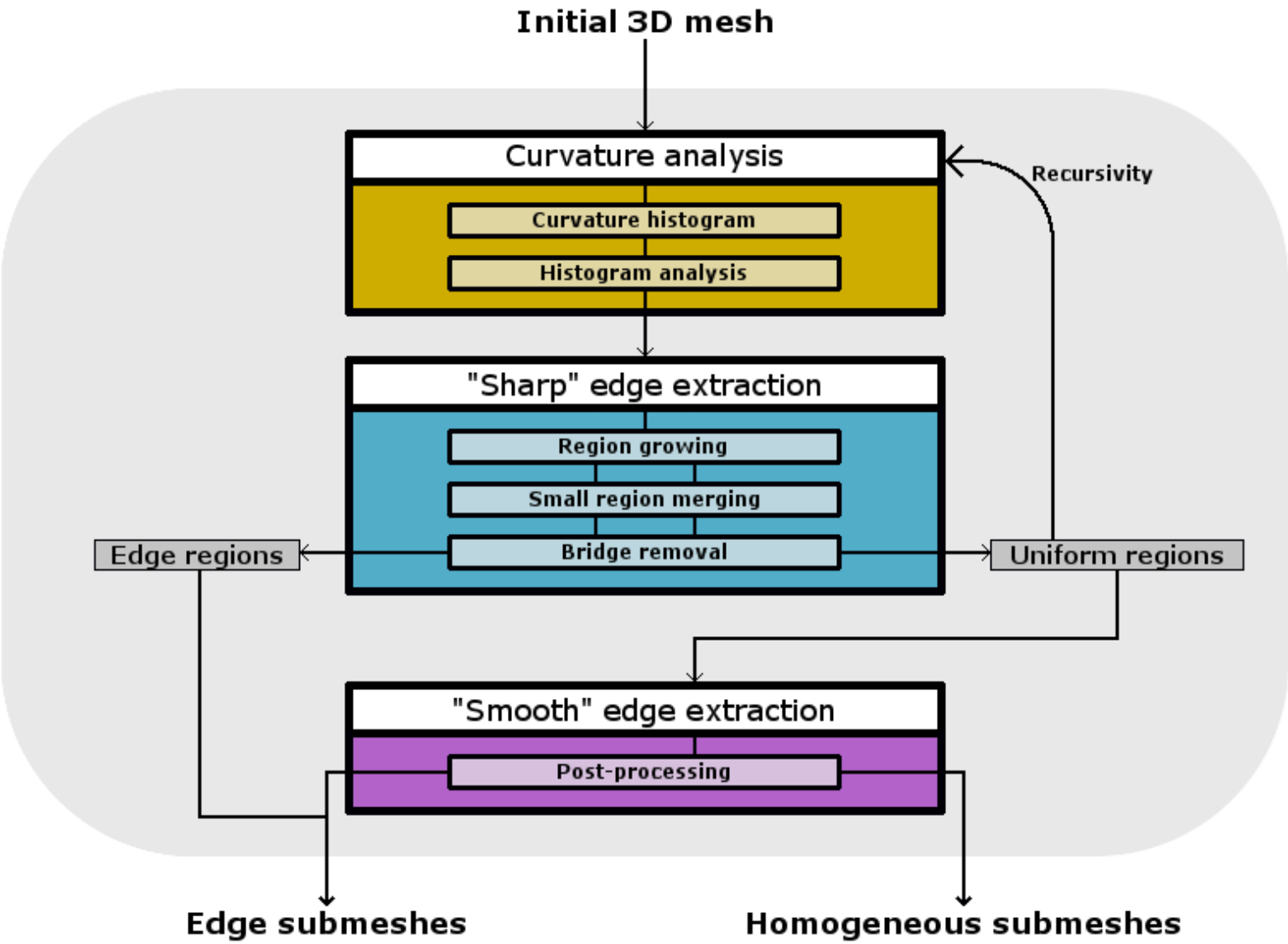
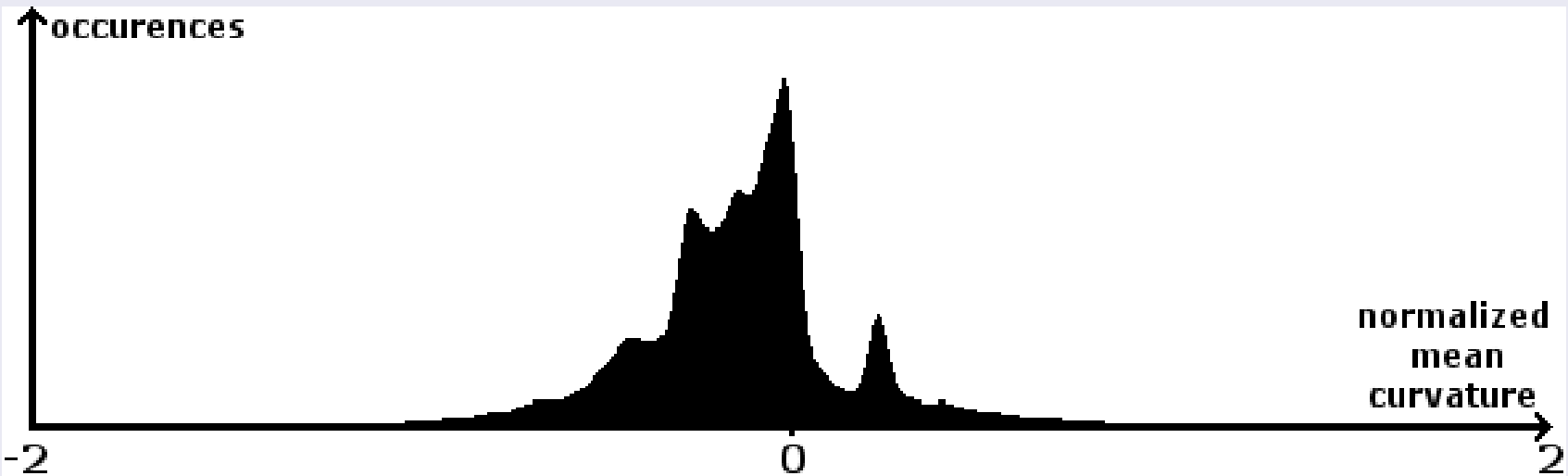
Method overview



Curvature analysis

Curvature histogram

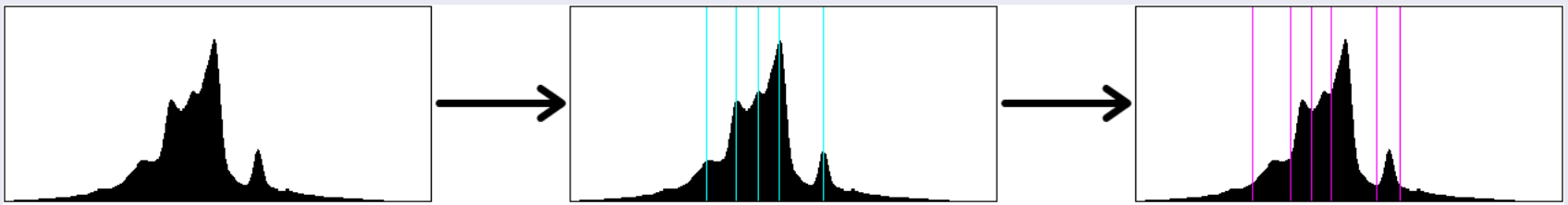
- Compute mean curvature at each vertex of the 3D mesh
- Normalize curvature values using the average edge length
- Construct a histogram using a Gaussian kernel estimation



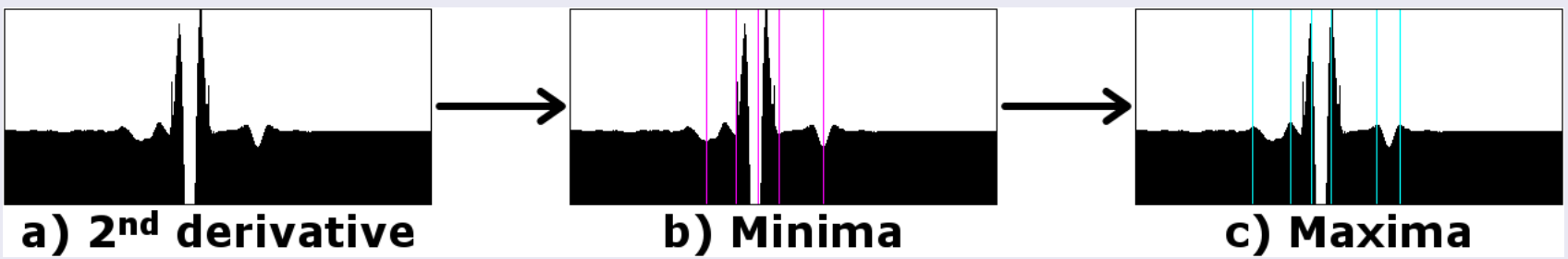
Curvature analysis

Histogram analysis

- Detect positions of “peaks” and “valleys”



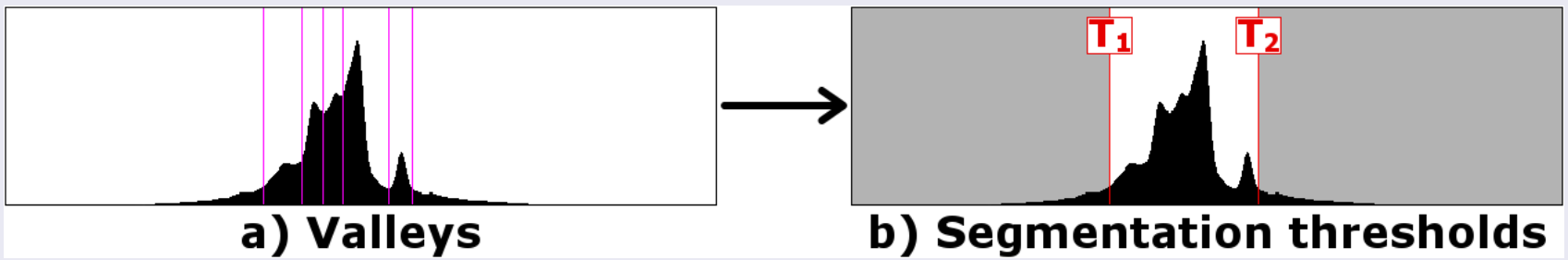
- Local minima in second derivative correspond to peaks in histogram
- Local maxima in second derivative correspond to valleys in histogram

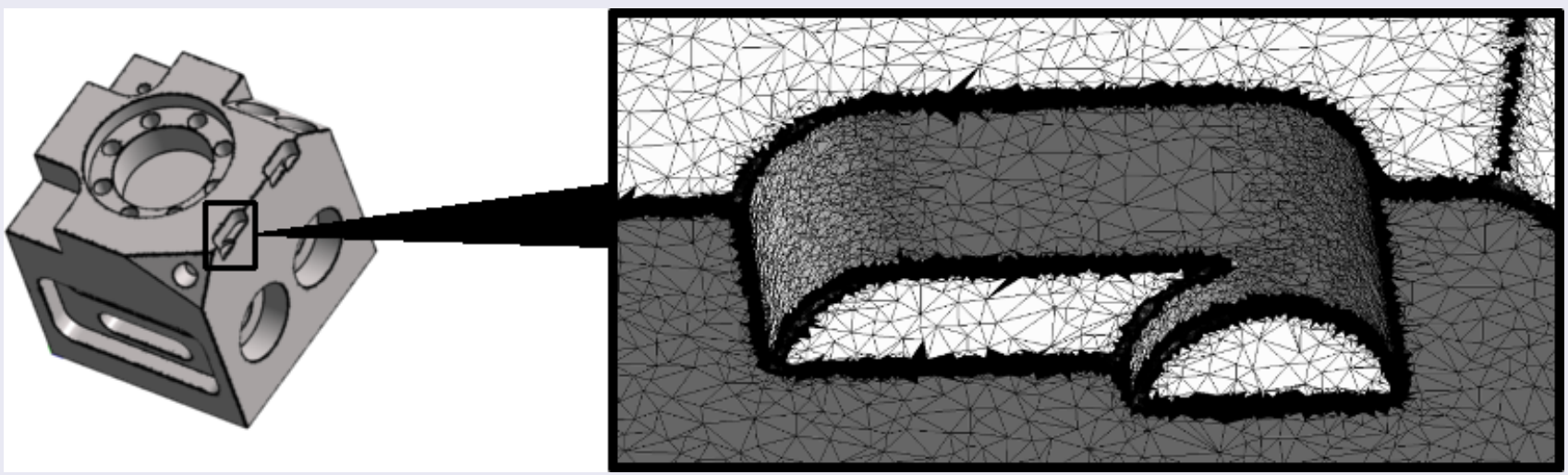


Curvature analysis

Curvature thresholding

- Use extremal valleys as curvature thresholds





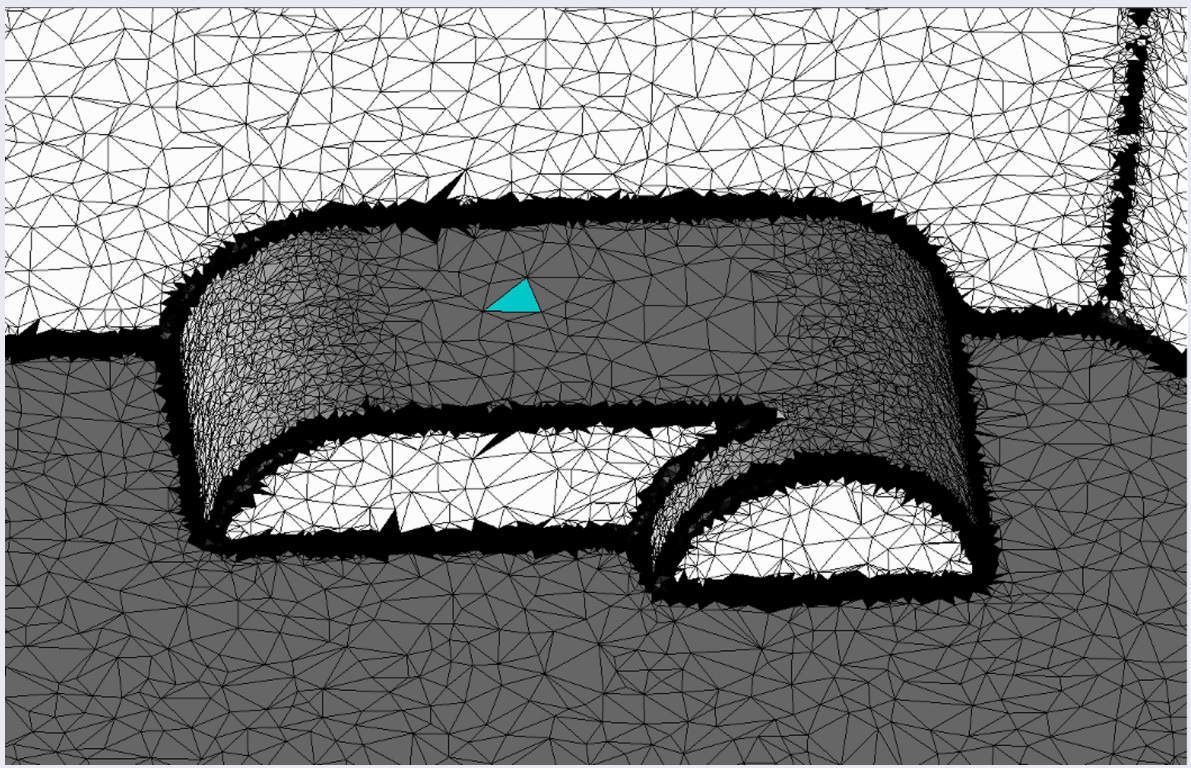
$]T_1, T_2[\rightarrow$ homogeneous triangles (white)

$]-\infty, T_1] \cup [T_2, +\infty[\rightarrow$ edge triangles (black)

“Sharp” edge extraction

Region growing

- Retrieve homogeneous and “edge” regions by propagation



Take a triangle and assign a unique ID

“Sharp” edge extraction

Region growing

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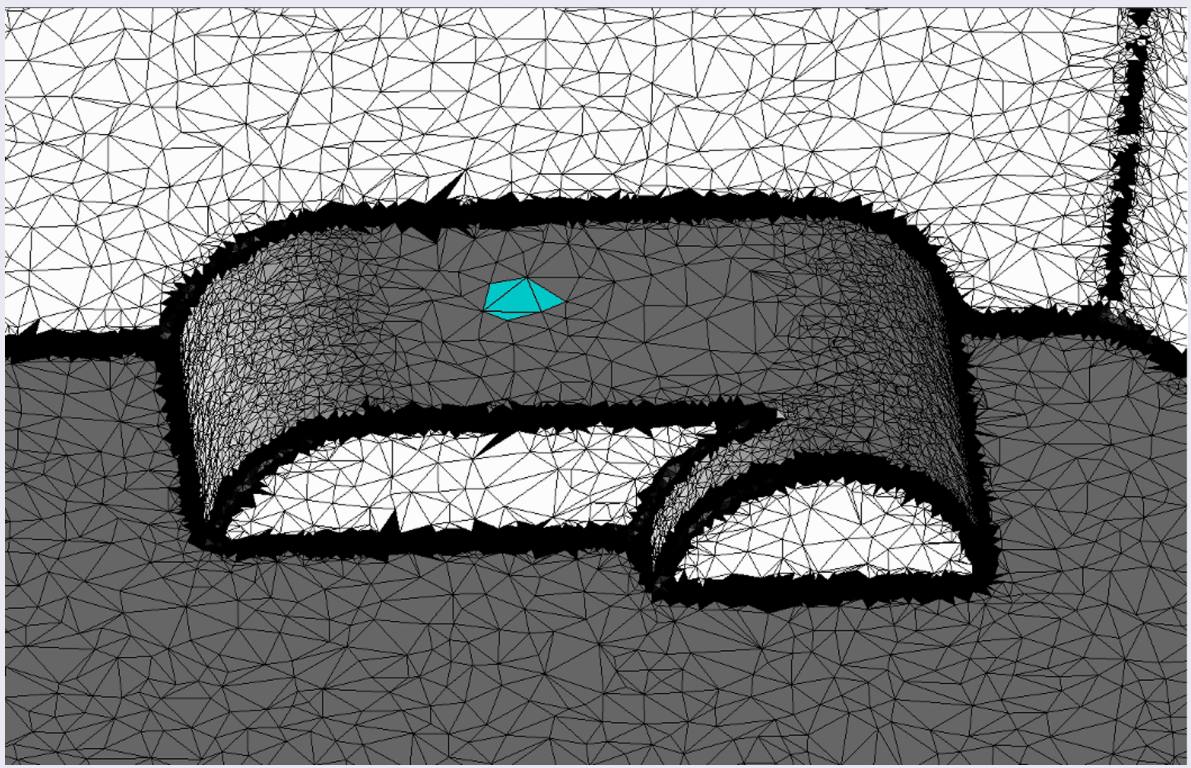
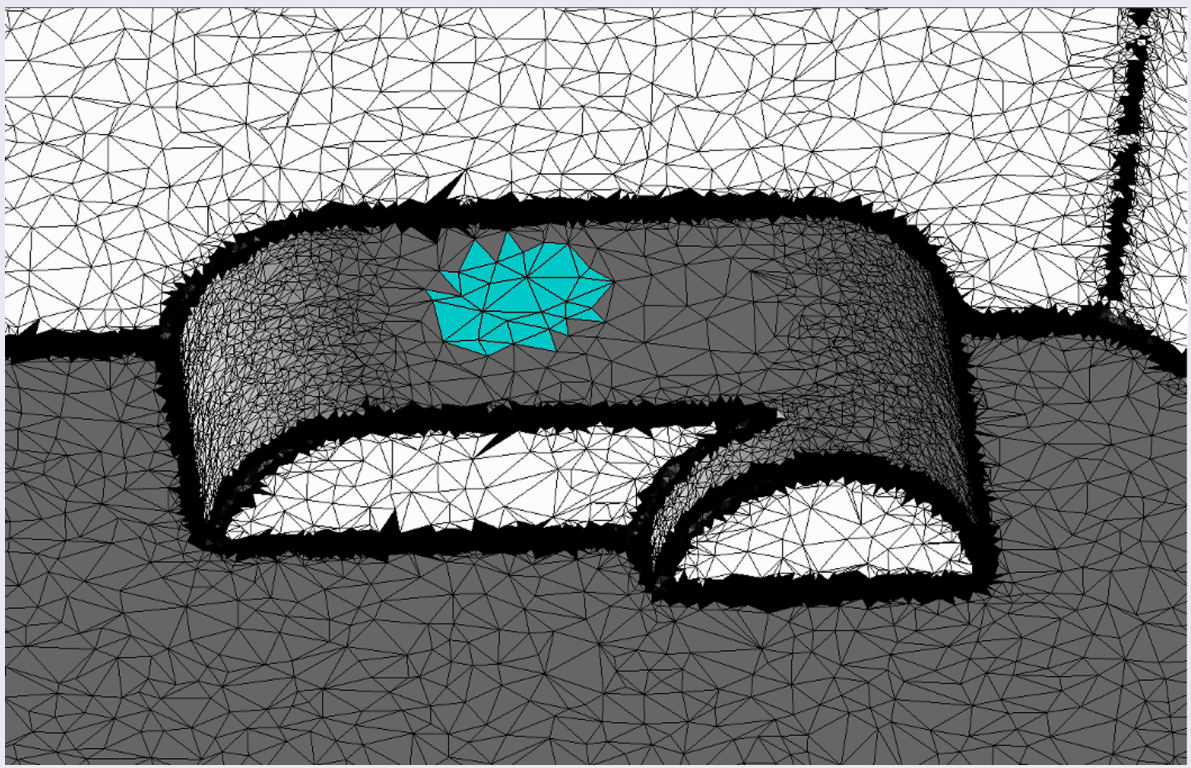


Propagate ID on its neighbors

“Sharp” edge extraction

Region growing

- Retrieve homogeneous and “edge” regions by propagation



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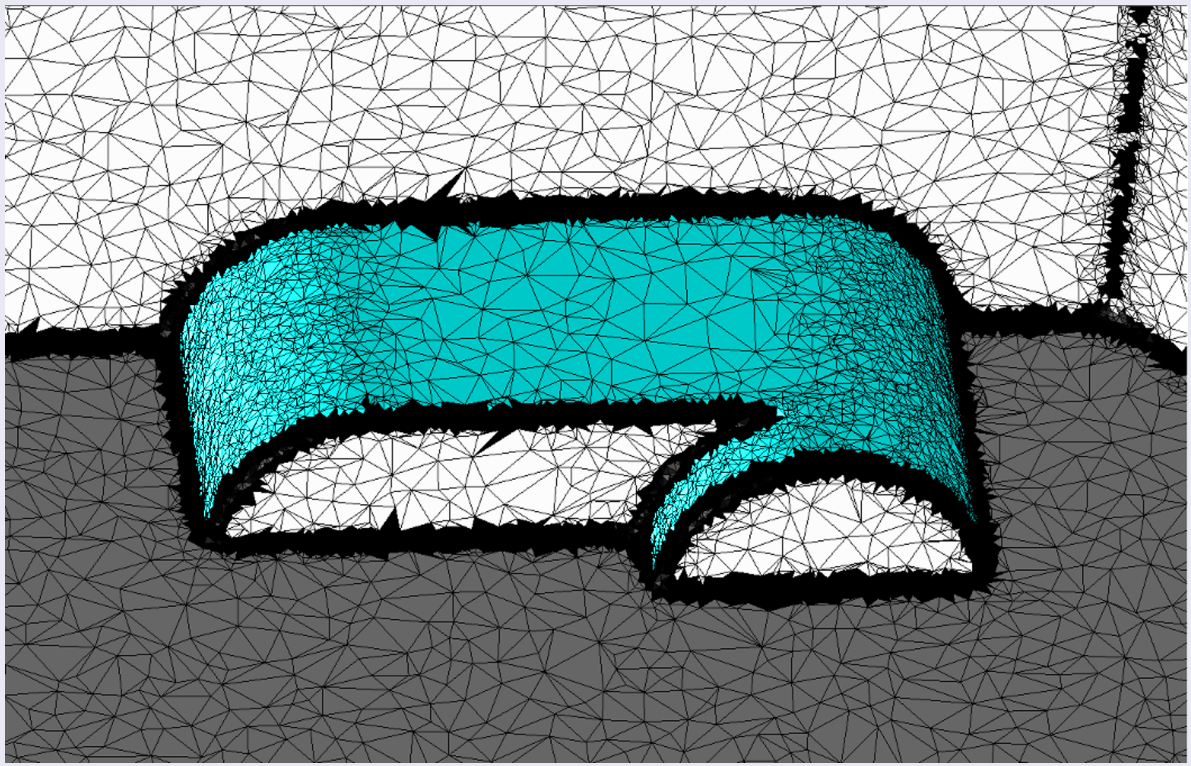

Until it reaches “edge” triangles

“Sharp” edge extraction

Region growing

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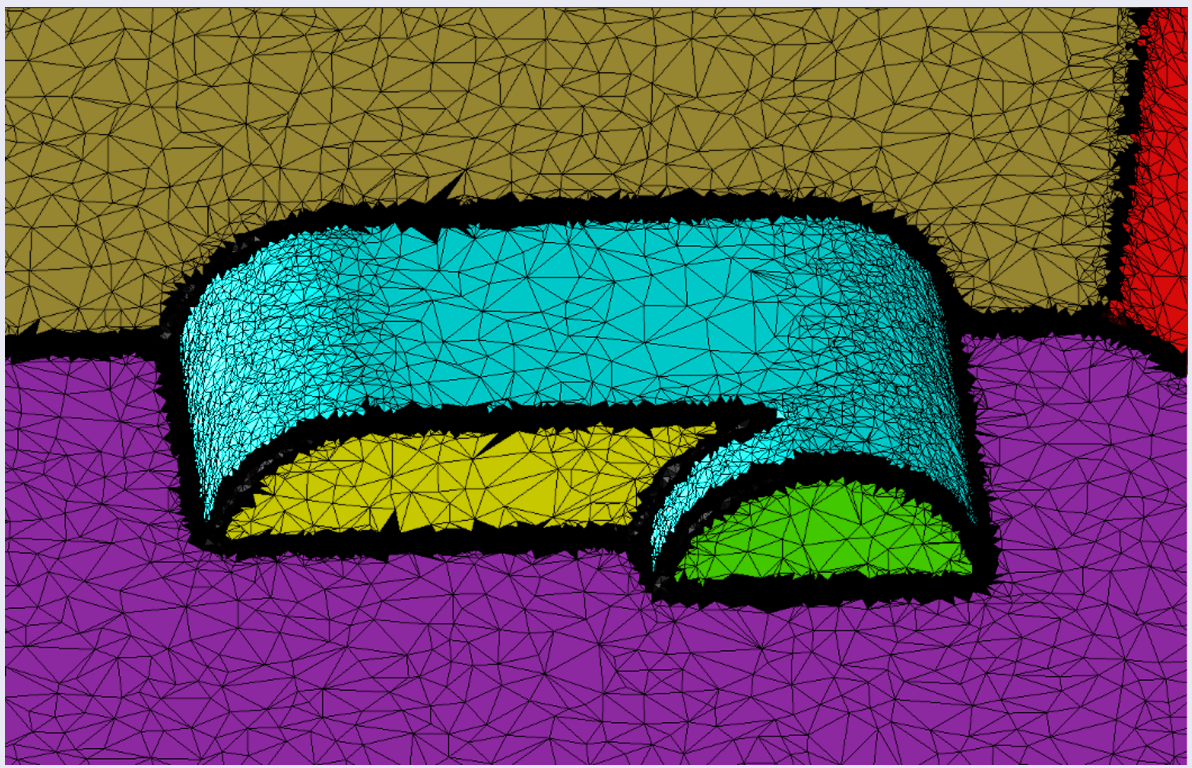
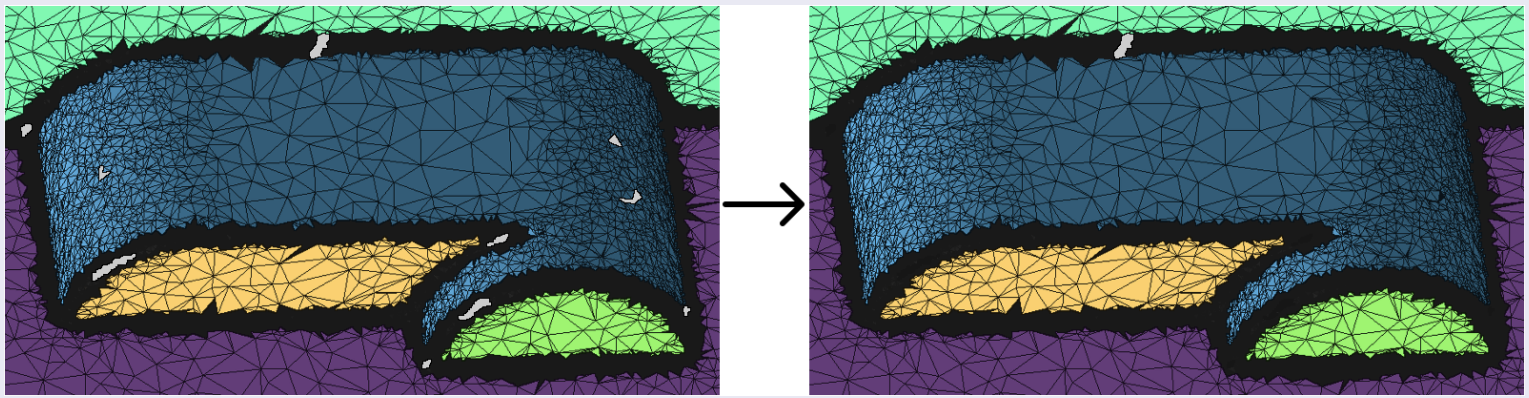


Start again with a new triangle until all triangles are processed

“Sharp” edge extraction

Over-segmentation: small region merging

- Merge small regions included in larger ones



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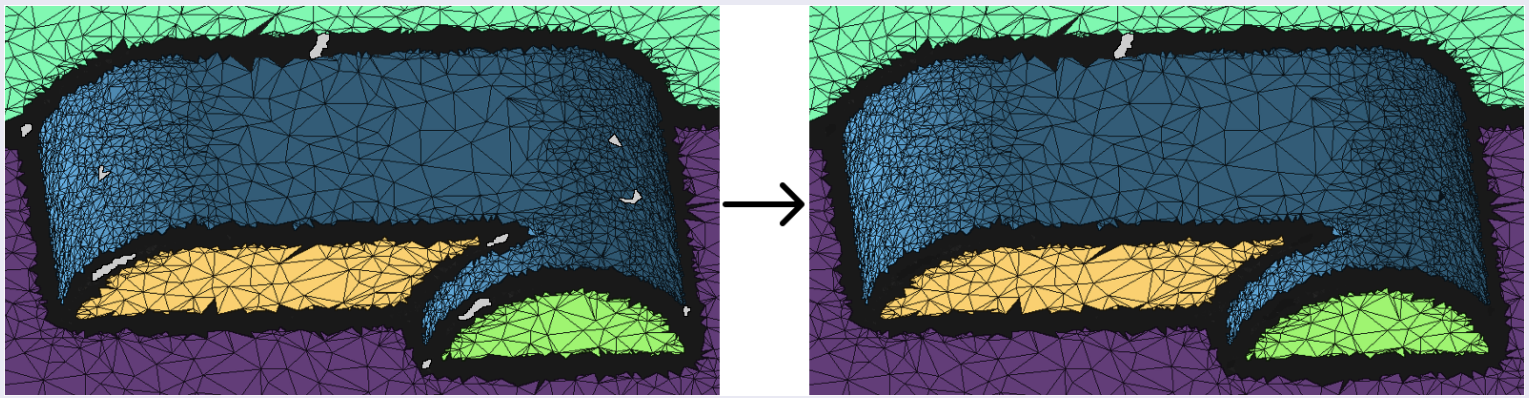
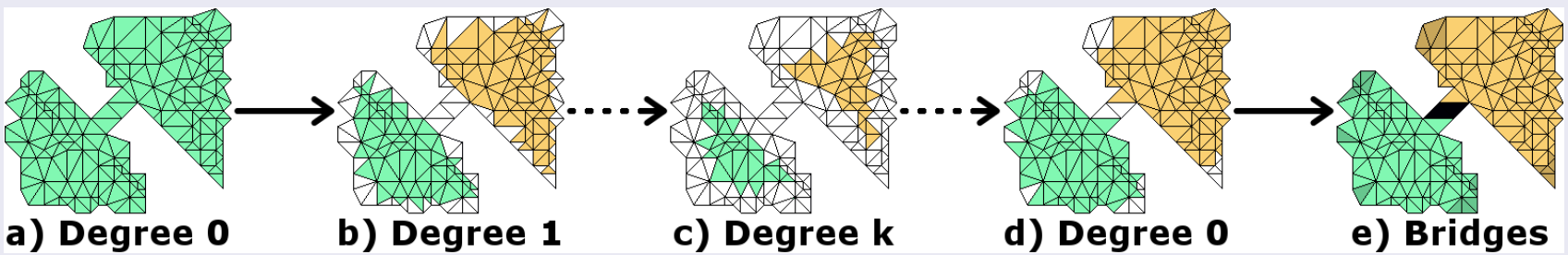


Under-segmentation: bridge removal

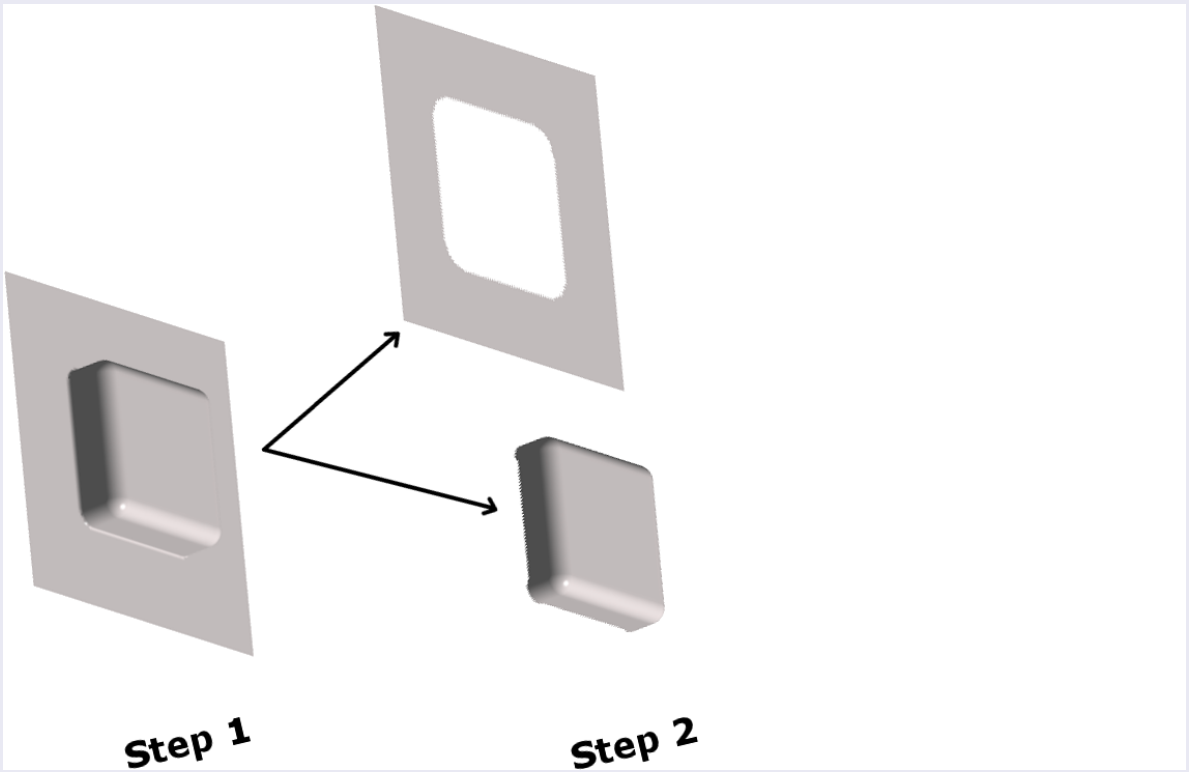
- Separate regions connected by thin strips of triangles



Recursivity

Recursive segmentation

- Start the process again on each region, with an updated histogram
- Stop when only one homogeneous region is found



Adaptive parameters at each step

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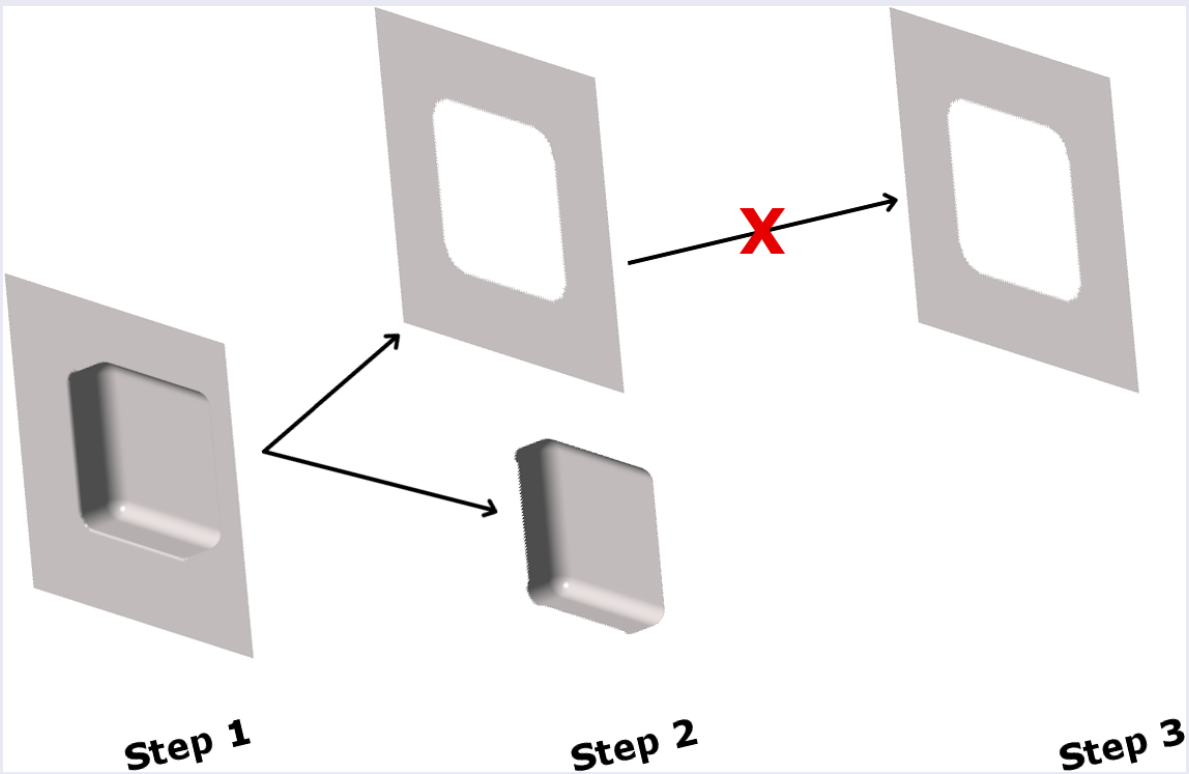

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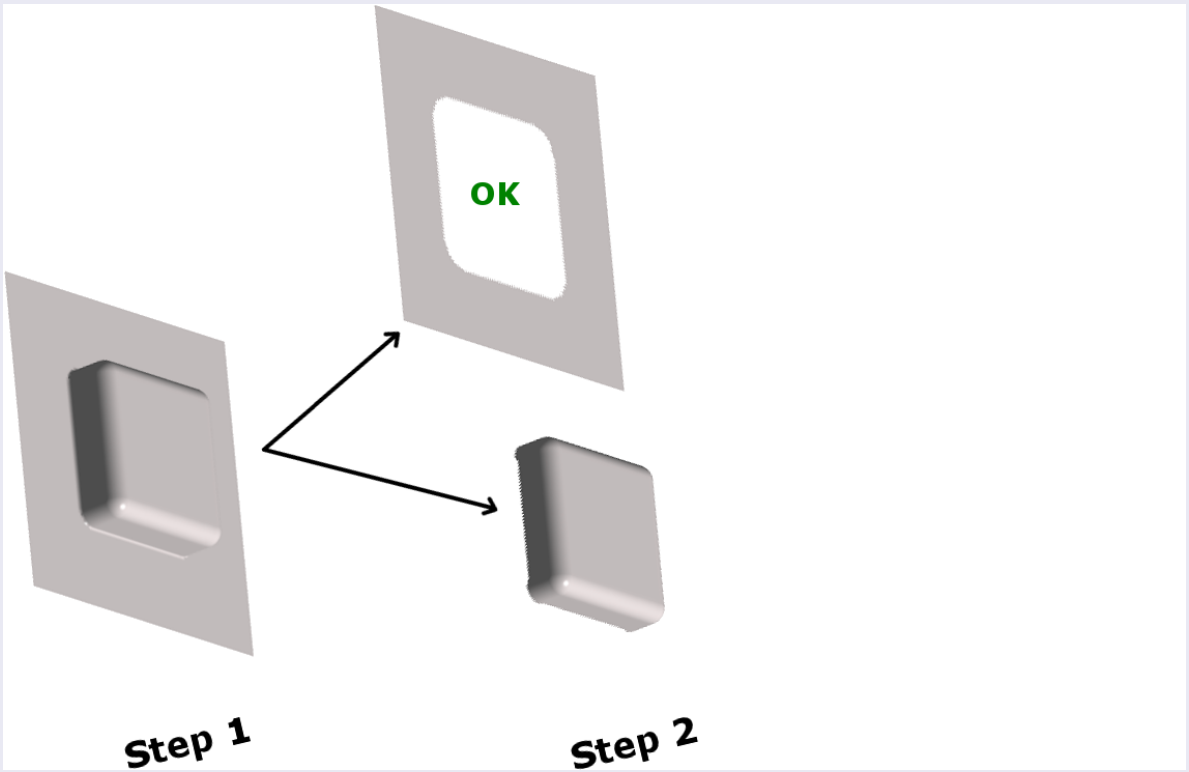

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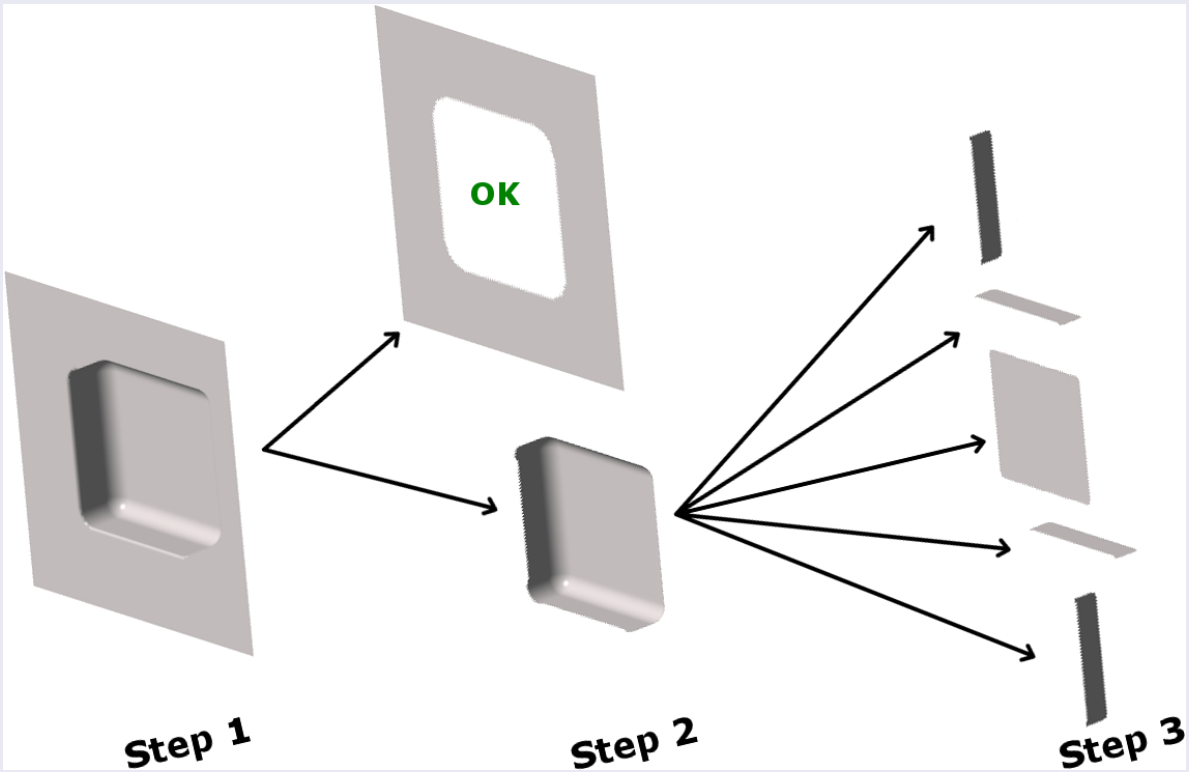

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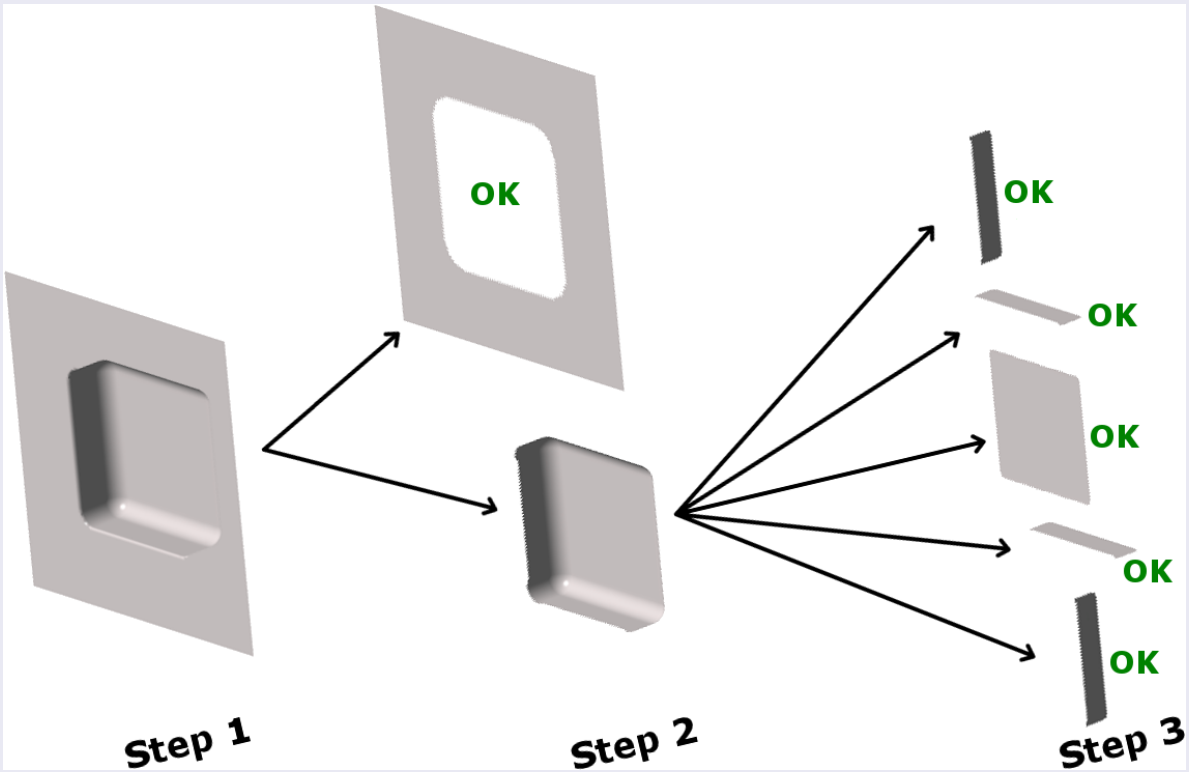
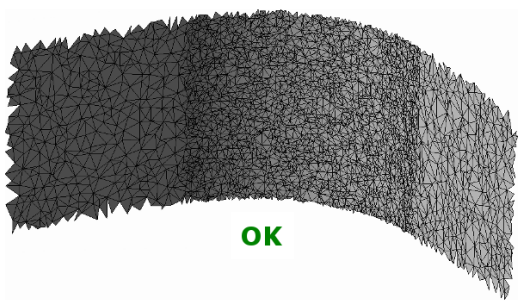


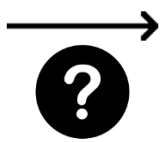
Adaptive parameters at each step

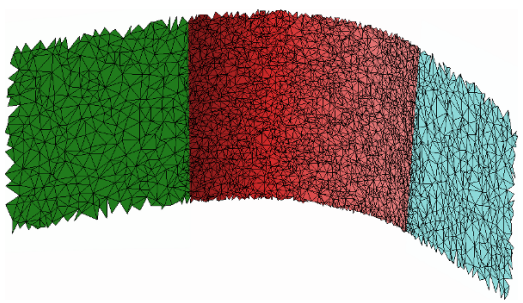
“Smooth” edge extraction

Multiple curvature thresholding

- Compute an updated curvature histogram for each region
- Separate homogeneous regions by a multiple thresholding
- Apply our segmentation process at each step (without recursion)







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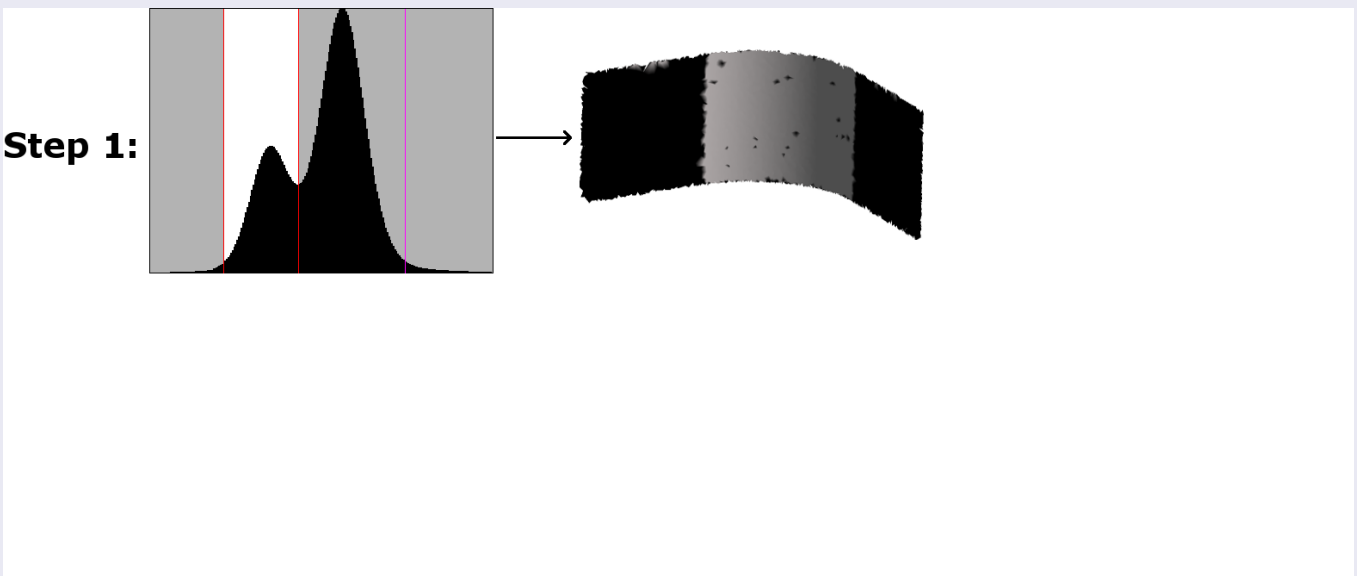

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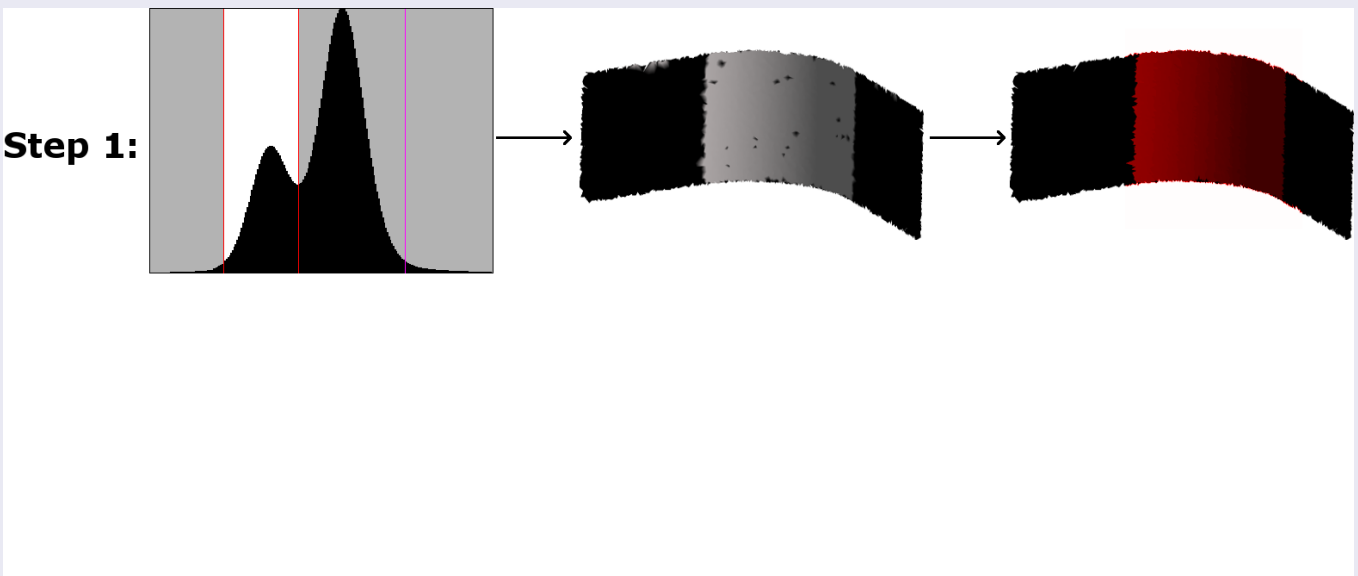

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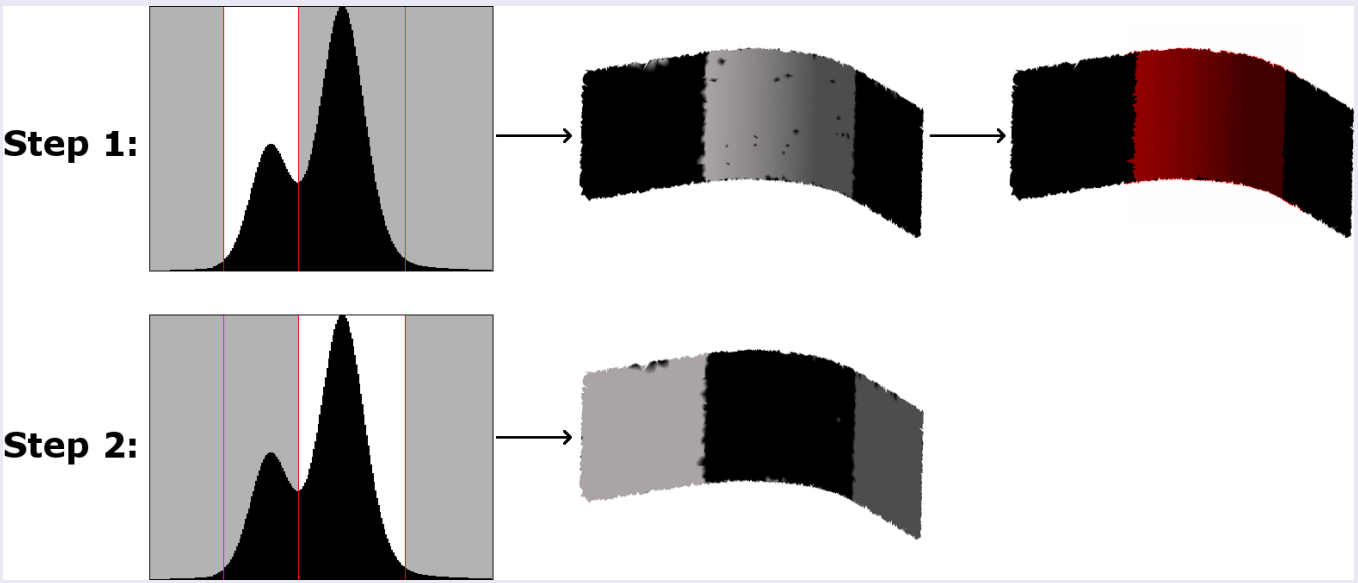

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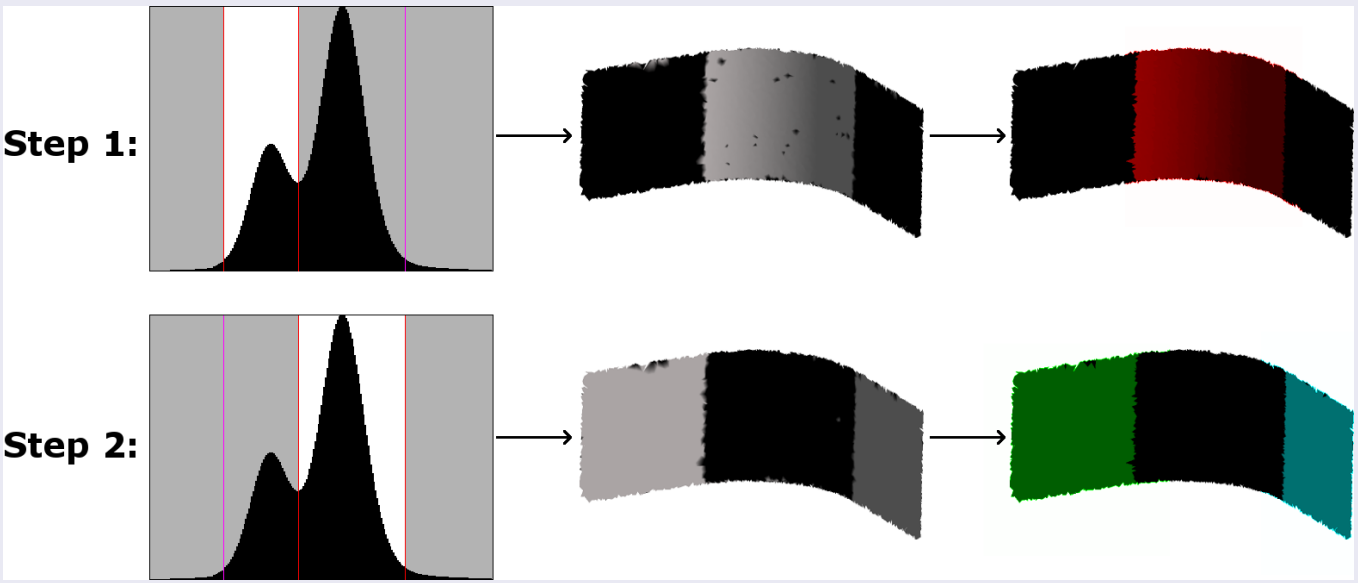

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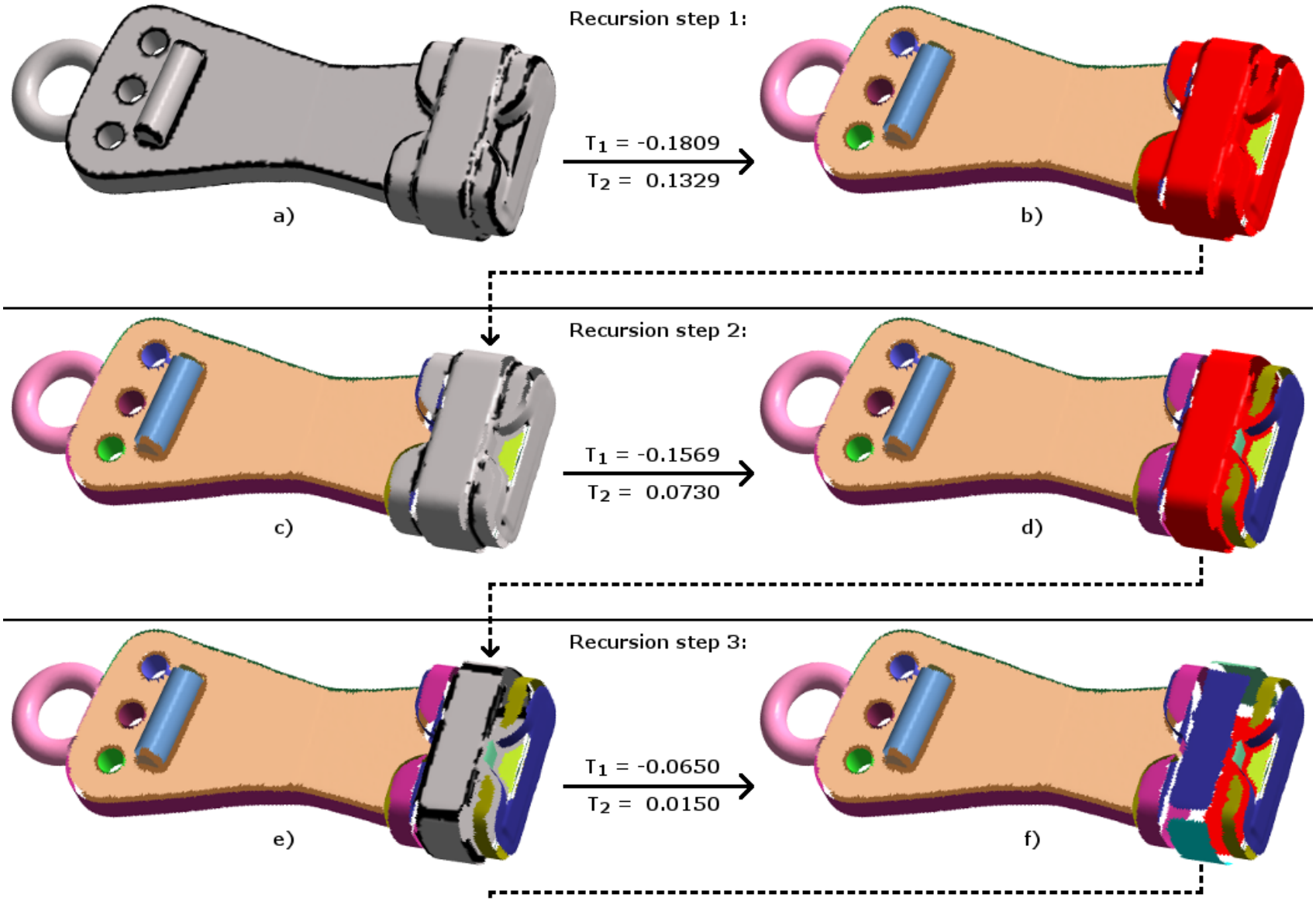
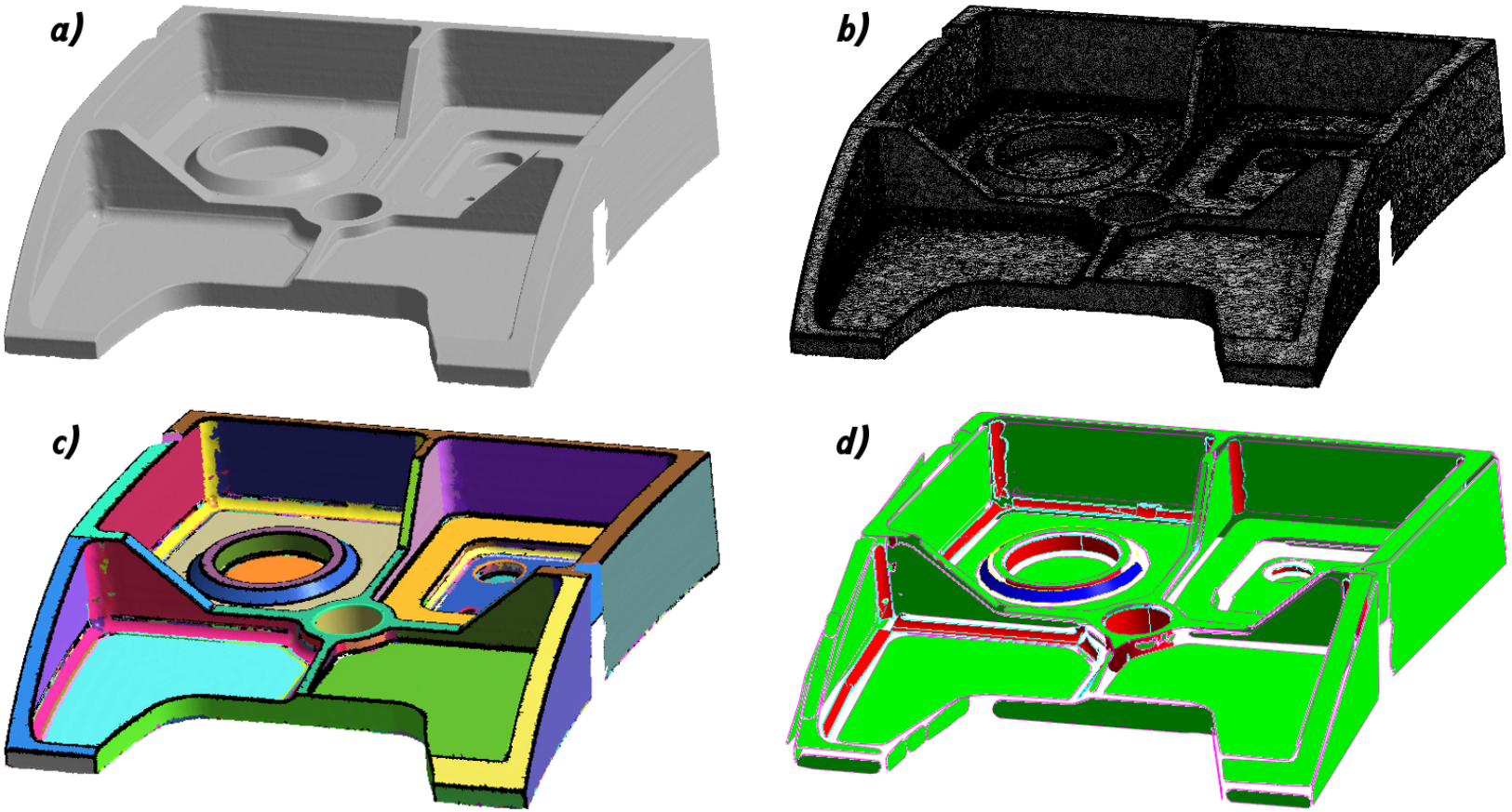
Experimental results

From 20,000 to 2,500,000 triangles — Different surface scanning devices — Heterogeneous noise

Recursivity example

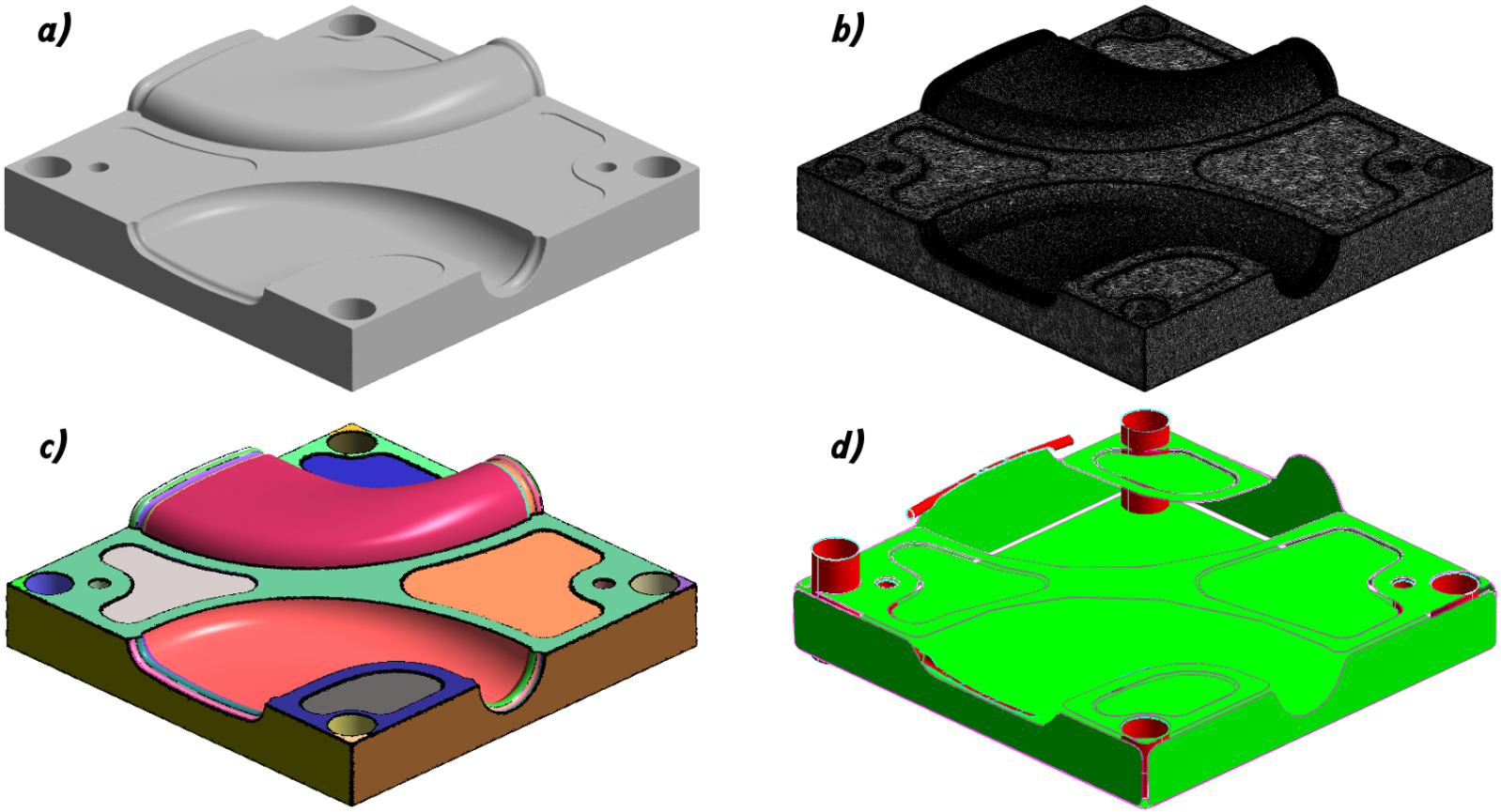


Back to context



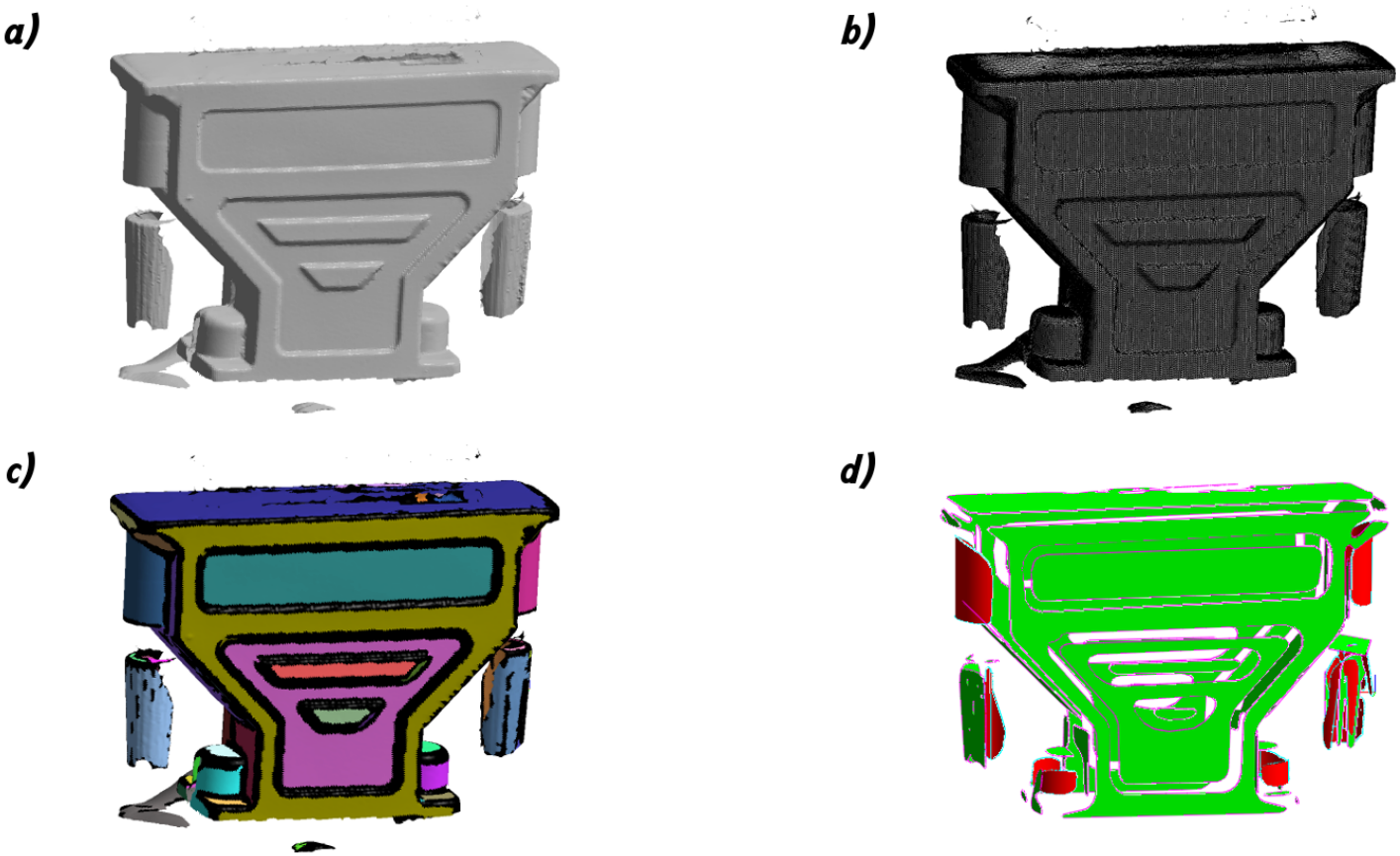
Segmentation: 799 296 triangles — 16 seconds — 70 regions — 94.3% with only one primitive

Back to context



Segmentation: 851 194 triangles — 13 seconds — 48 regions — 100% with only one primitive

Back to context



Segmentation: 195 853 triangles — 5 seconds — 72 regions — 100% with only one primitive

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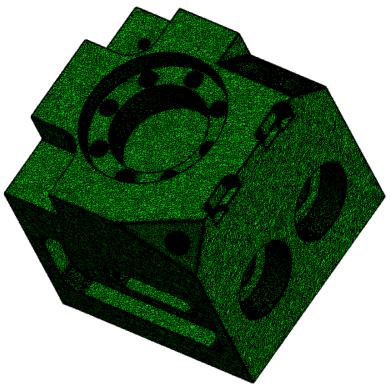
Conclusion

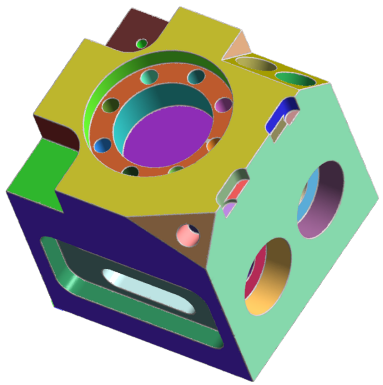
Results

Segmentation:

- Fast: 10-30 seconds for 1 million triangles
- Adaptive: compute parameters from input data at each step
- Automatic: no user action



Mesh



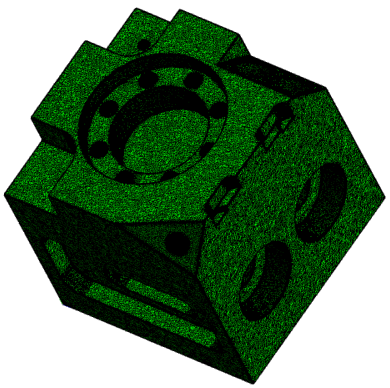
Submeshes

Conclusion

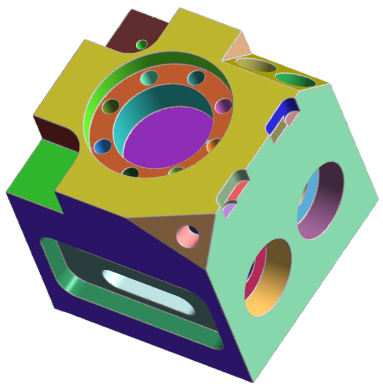
Results

Reverse engineering:

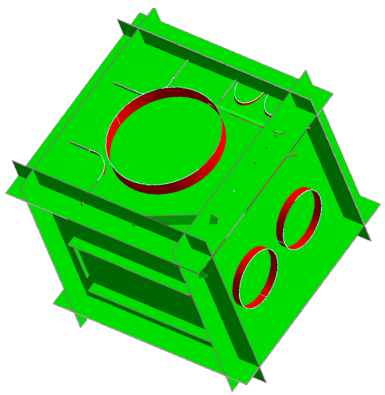
- Around 96% of obtained submeshes contain only one primitive
- Reduce computational cost (40 to 80%)
- Improve reconstruction accuracy (+50%)



Mesh



Submeshes



Primitives

Perspectives

Accuracy

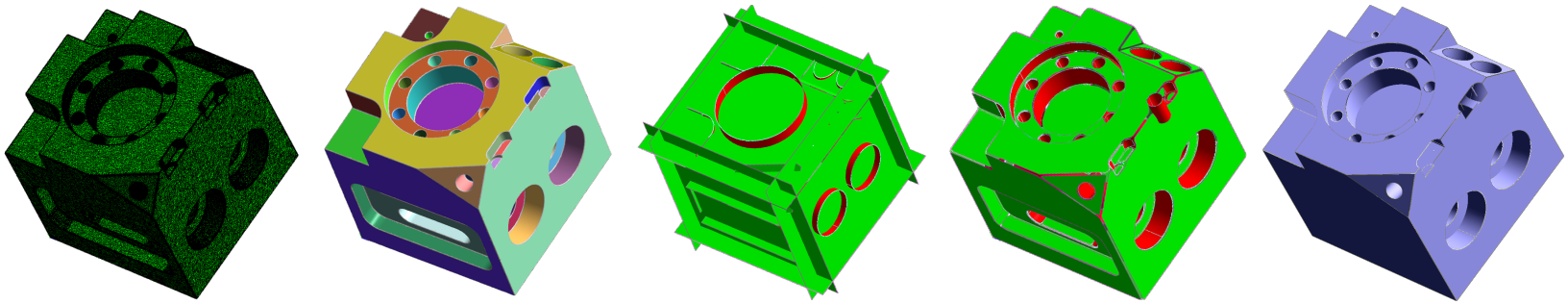
Optimize some parameters, like bin number for histogram construction.

Extensibility

Adapt our approach for natural objects, for example to use it for medical image analysis.

Thank you

Some questions?



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Silvère Gauthier, R. Bénière, W. Puech, G. Pouessel, G. Subsol,
Digitized 3D mesh segmentation based on curvature analysis, 2017