

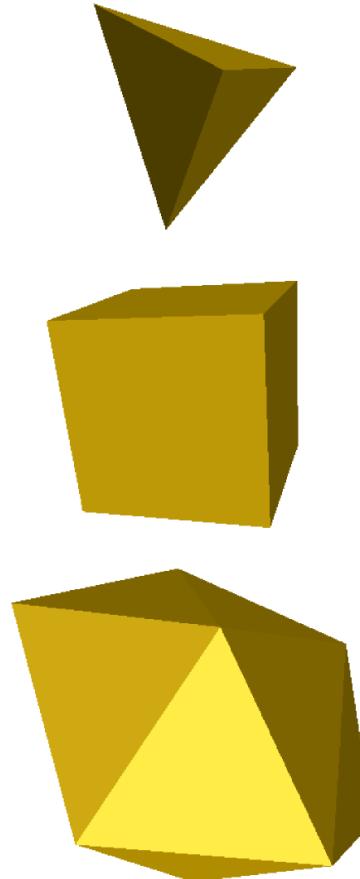


Minimizing Edge Length to Connect Sparsely Sampled Unstructured Point Sets in 3D

S. Ohrhallinger^{1,2}, S. Mudur² and M. Wimmer¹

¹Vienna University of Technology, ²Concordia University, Montréal

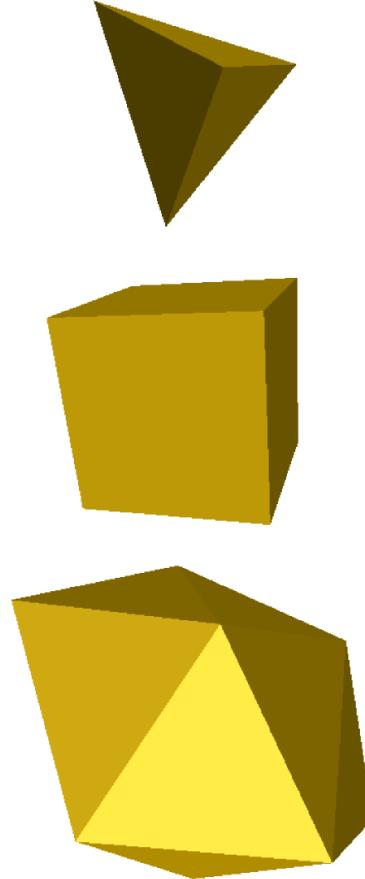
Surface Reconstruction



Surface Reconstruction



Dense is easy



Sparse is hard



State of the Art

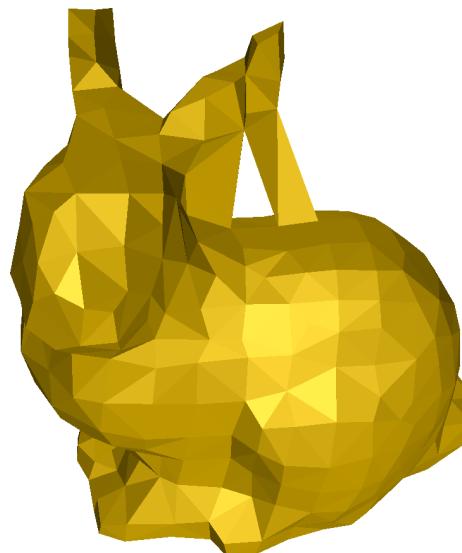
Wrap



Tight Cocone



Shrink



Ours

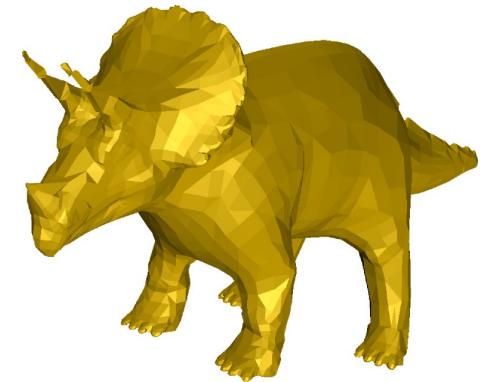


Problem Domain

Fitting



Interpolating



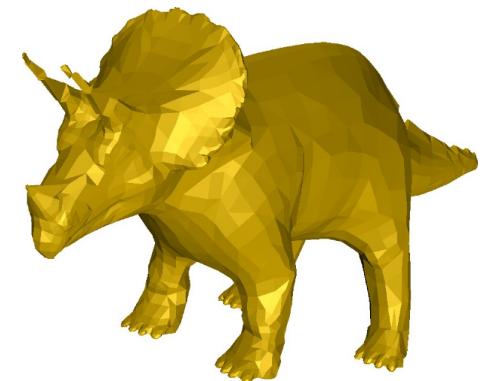
Problem Domain

Fitting

Too smooth



Interpolating



Problem Domain

Fitting



Too smooth

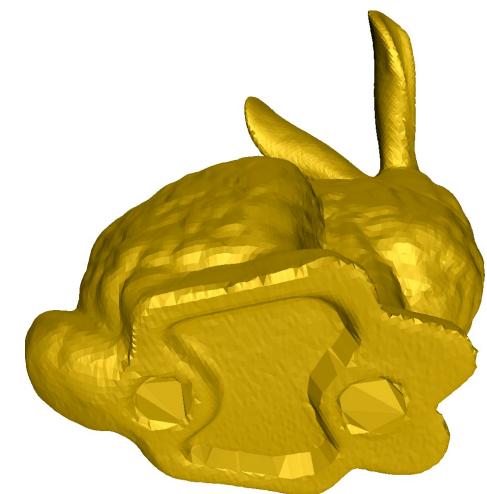
Bound Holes



Interpolating



Closed Mesh



Problem Domain

Fitting



Too smooth

Bound Holes



Parameter

Interpolating



Closed Mesh



Problem Domain

Fitting



Too smooth

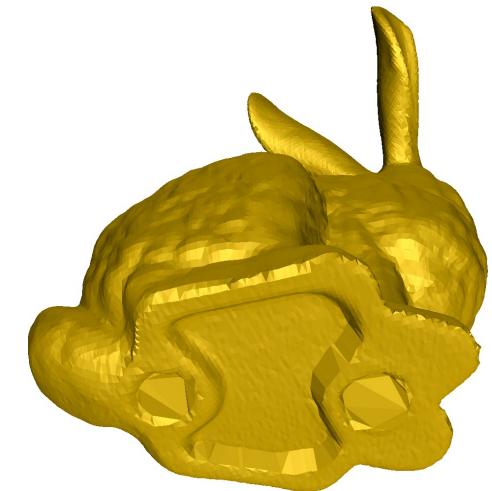
Interpolating



Bound Holes



Closed Mesh



Parameter

Connect points with polyhedron B in DT , close to smooth surface S



α -Shapes
[4,5]



α -Shapes
[4,5]

Local Tangent Planes
[8,9,10,11]



α -Shapes
[4,5]

Local Tangent Planes
[8,9,10,11]

Umbrella Matching
[12,13]



α -Shapes
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Umbrella Matching
[12,13]

Sculpturing
[8,14,15,18]



Related Work

α -Shapes
[4,5]

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[8,9,10,11]

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[12,13]

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Voronoi Filtering
[3,16,17]



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Optimization
[26,27,28]



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[3,16,17]

Flow
[20,21,22,23,24,25]

Optimization
[26,27,28]



Related Work

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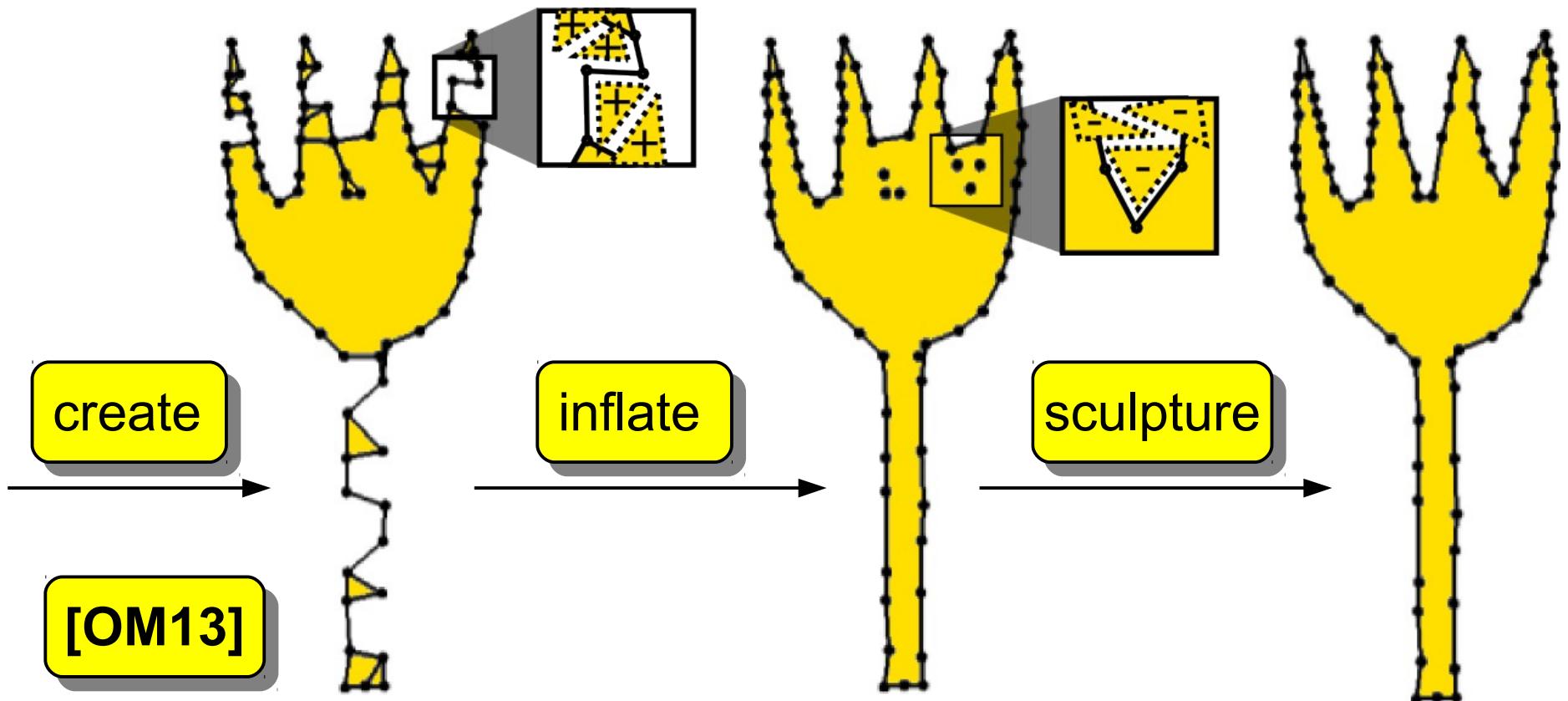
Flow
[20,21,22,23,24,25]

Optimization
[26,27,28]

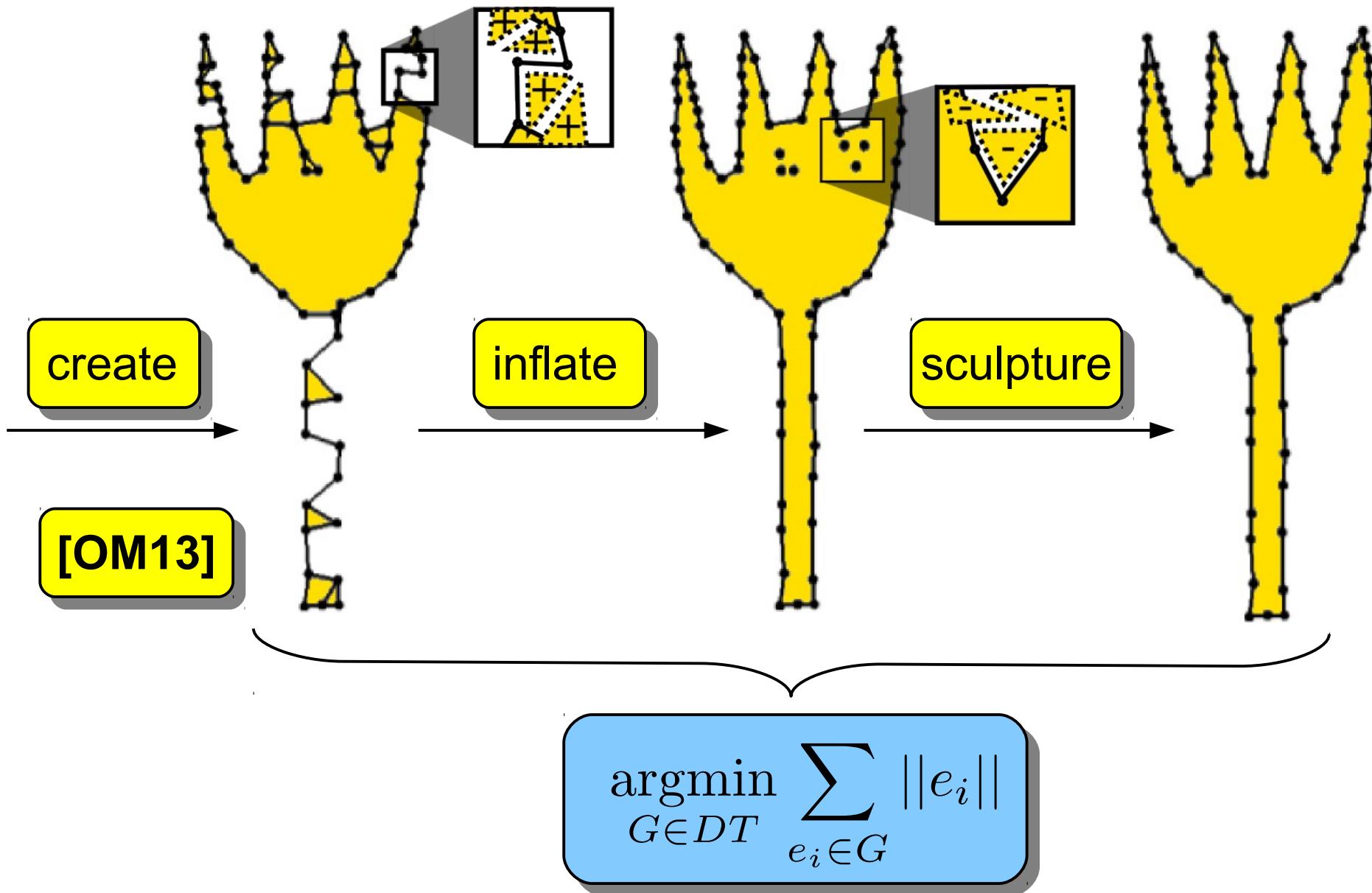
Ours



We extend our 2D Method



We extend our 2D Method



Minimization Objective

$$\mathbb{R}^2 : B_{min} = \operatorname{argmin}_{B \in \mathbf{B}} \sum_{e \in B} \|e\|$$

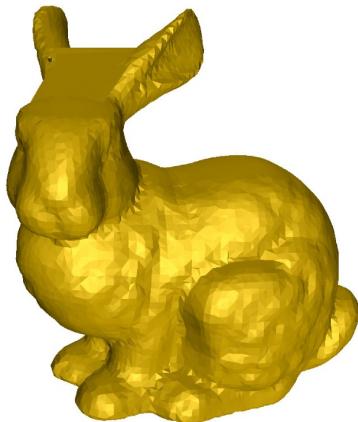
$\mathbb{R}^3 :$



Minimization Objective

$$\mathbb{R}^2 : B_{min} = \operatorname{argmin}_{B \in \mathcal{B}} \sum_{e \in B} \|e\|$$

$\mathbb{R}^3 :$



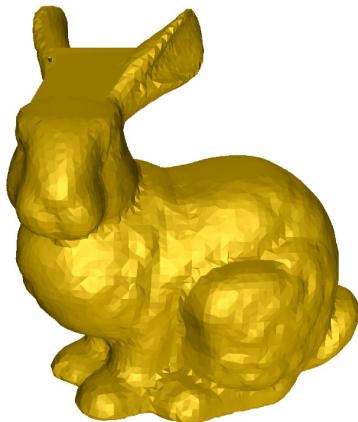
Circumradius



Minimization Objective

$$\mathbb{R}^2 : B_{min} = \operatorname{argmin}_{B \in \mathcal{B}} \sum_{e \in B} \|e\|$$

$\mathbb{R}^3 :$



Circumradius

Aspect ratio



Minimization Objective

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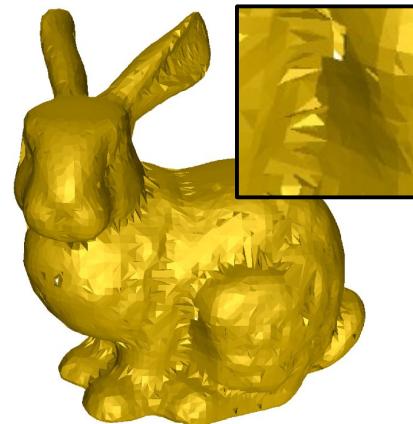
$\mathbb{R}^3 :$



Circumradius



Aspect ratio



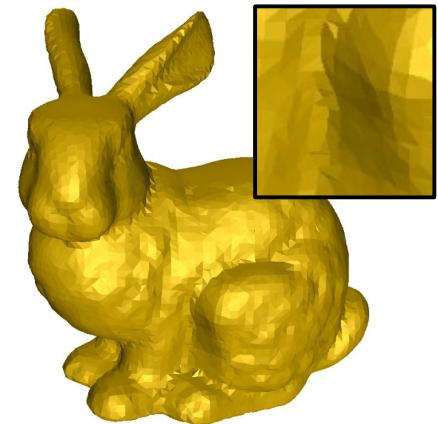
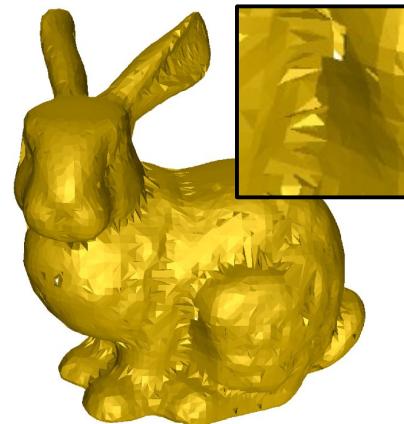
Area



Minimization Objective

$$\mathbb{R}^2 : B_{min} = \operatorname{argmin}_{B \in \mathcal{B}} \sum_{e \in B} \|e\|$$

$$\mathbb{R}^3 :$$



Circumradius

Aspect ratio

Area

Longest edge
in triangle $\lambda(t)$



Minimization Objective

$$\mathbb{R}^2 : B_{min} = \operatorname{argmin}_{B \in \mathbf{B}} \sum_{e \in B} \|e\|$$

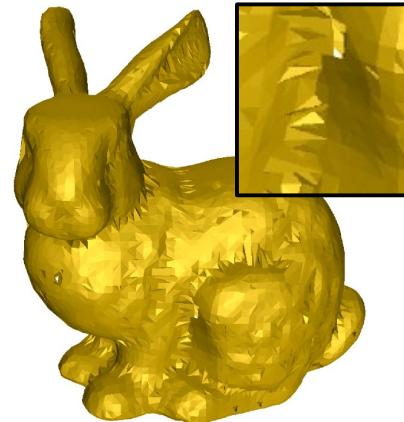
$$\mathbb{R}^3 : B_{min} = \operatorname{argmin}_{B \in \mathbf{B}} \sum_{t \in B} \lambda(t)$$



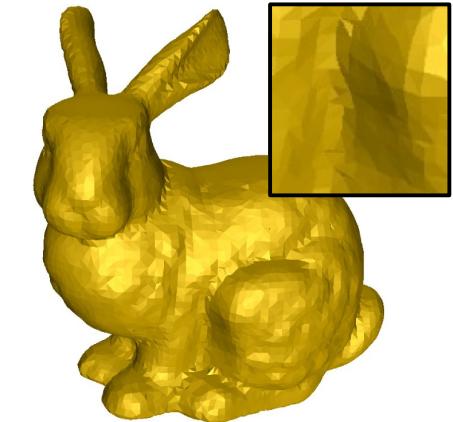
Circumradius



Aspect ratio



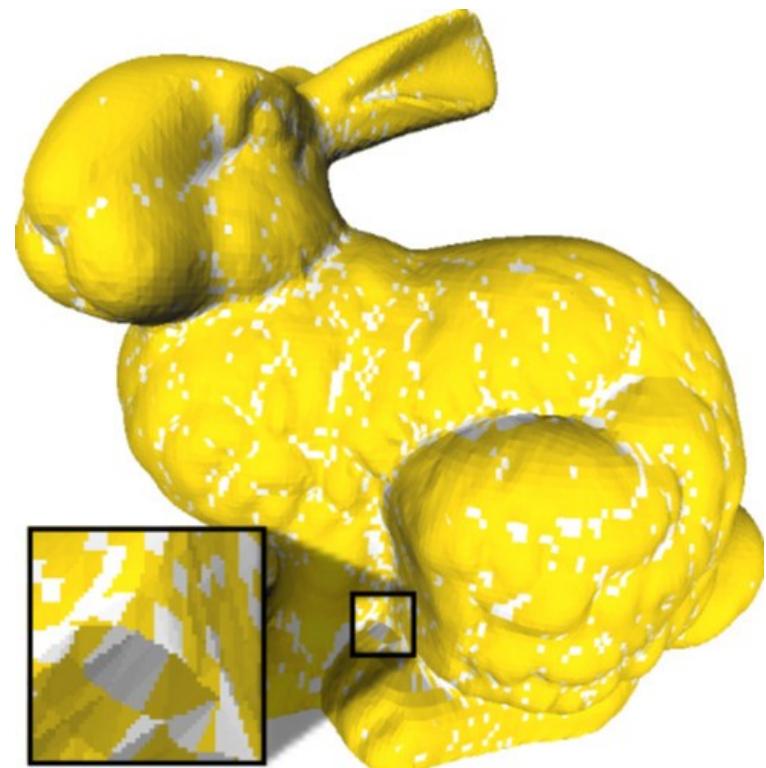
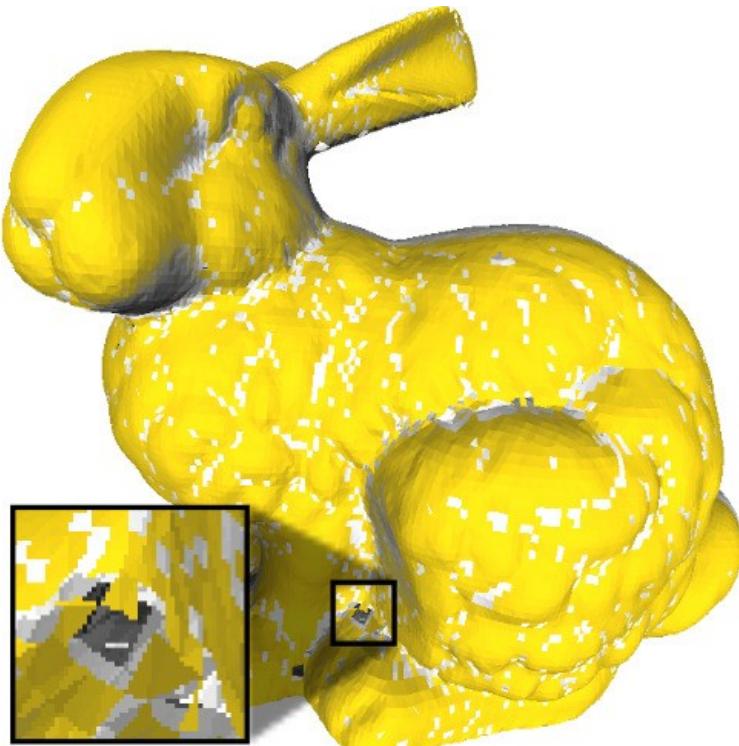
Area



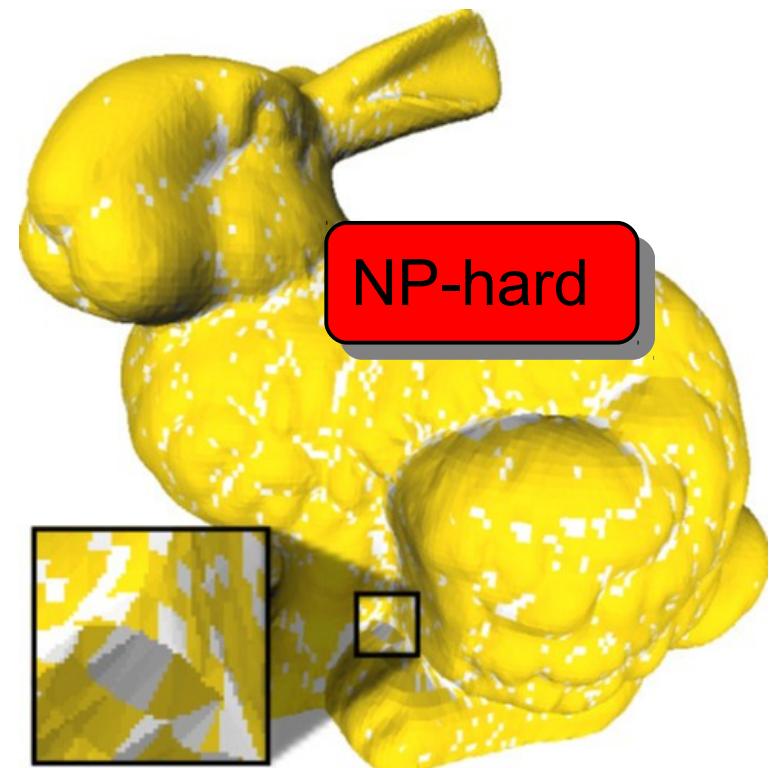
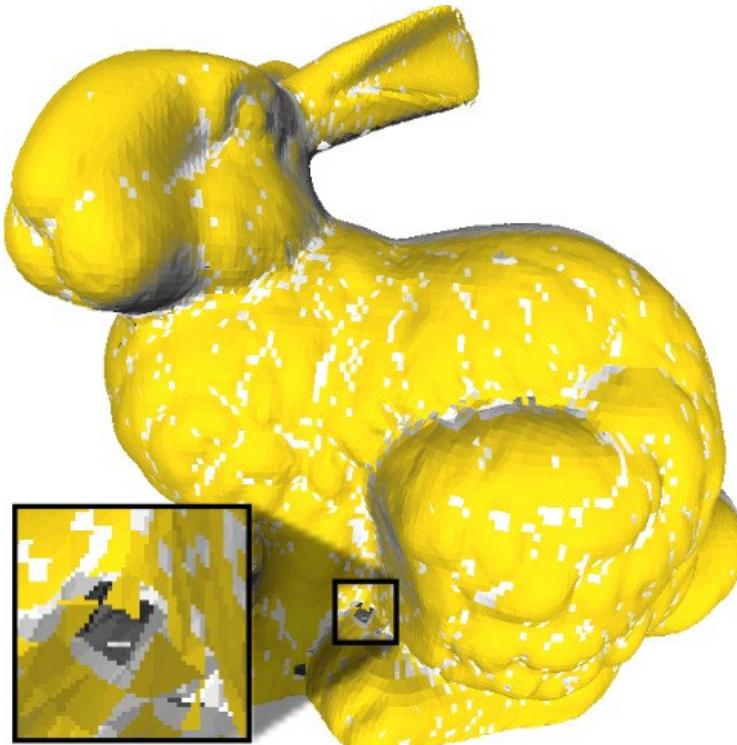
Longest edge
in triangle $\lambda(t)$



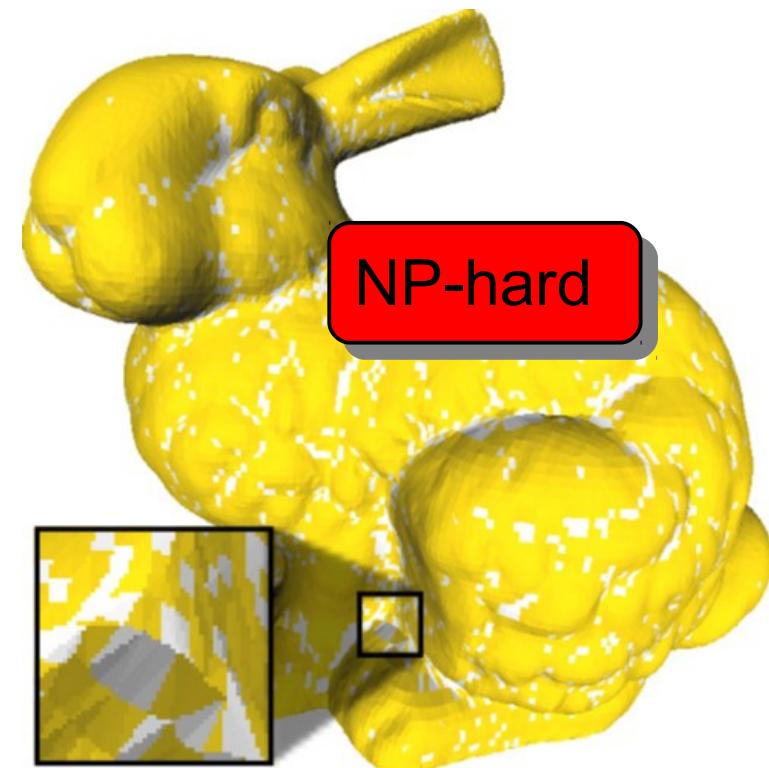
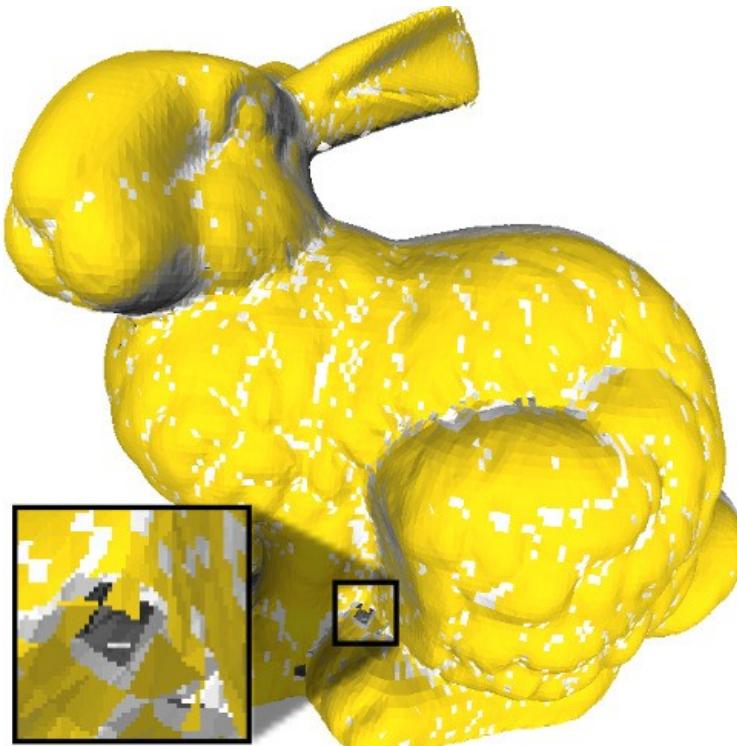
A fast Approximation



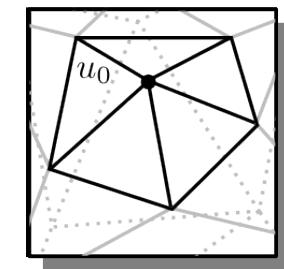
A fast Approximation



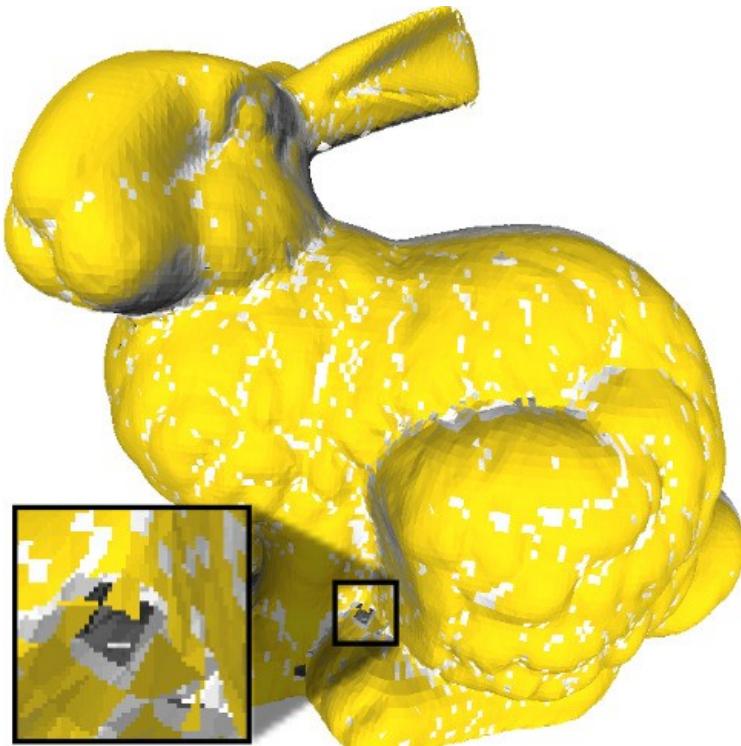
A fast Approximation



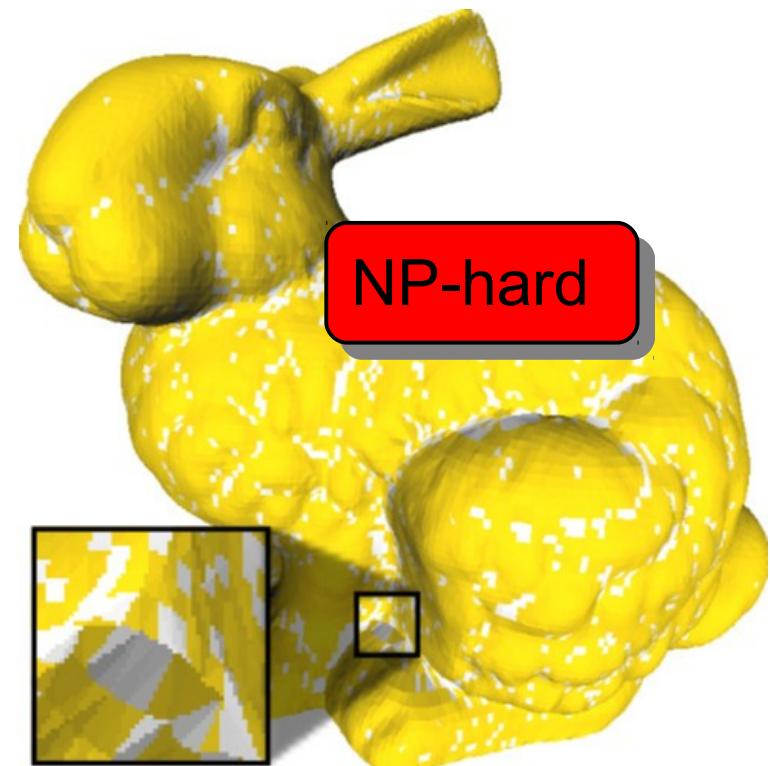
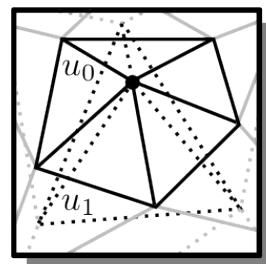
$$B_{min} : u = 1$$



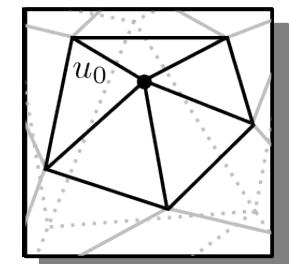
A fast Approximation



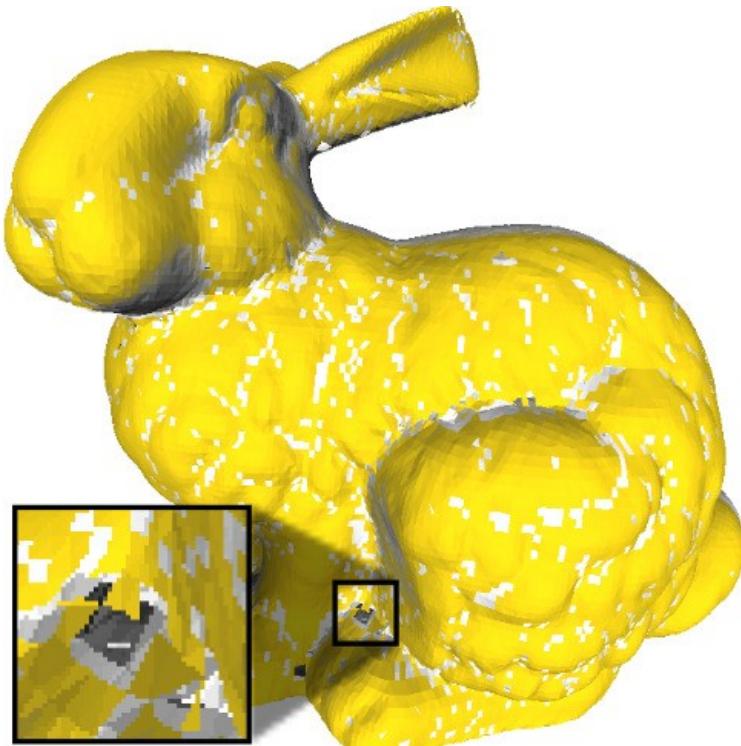
$BC_{min} : u \geq 1$



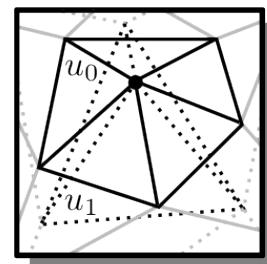
$B_{min} : u = 1$



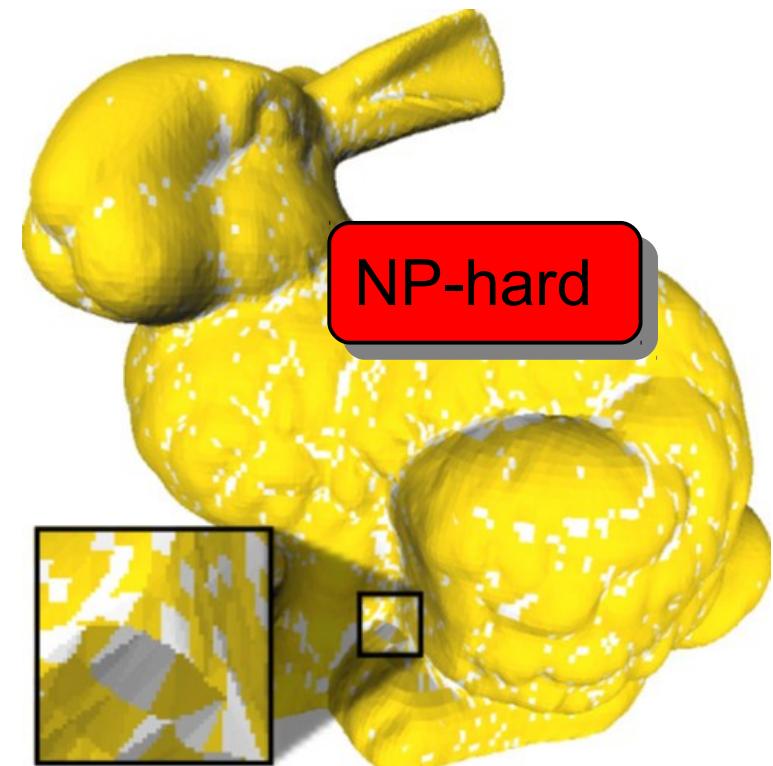
A fast Approximation



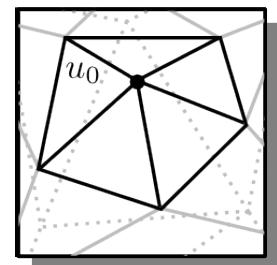
$$BC_{min} : u \geq 1$$



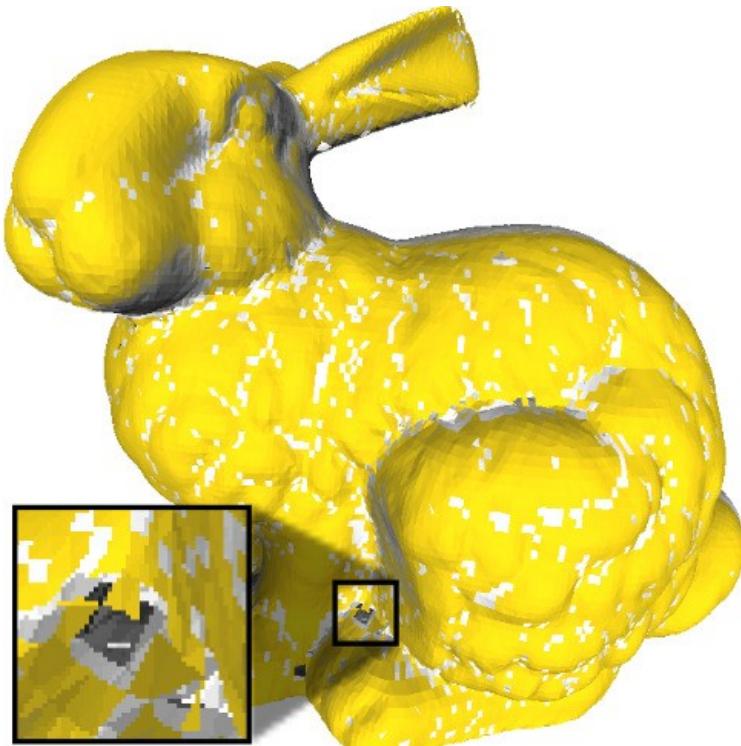
Still NP-hard?



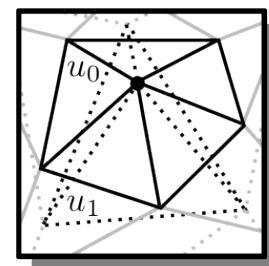
$$B_{min} : u = 1$$



A fast Approximation

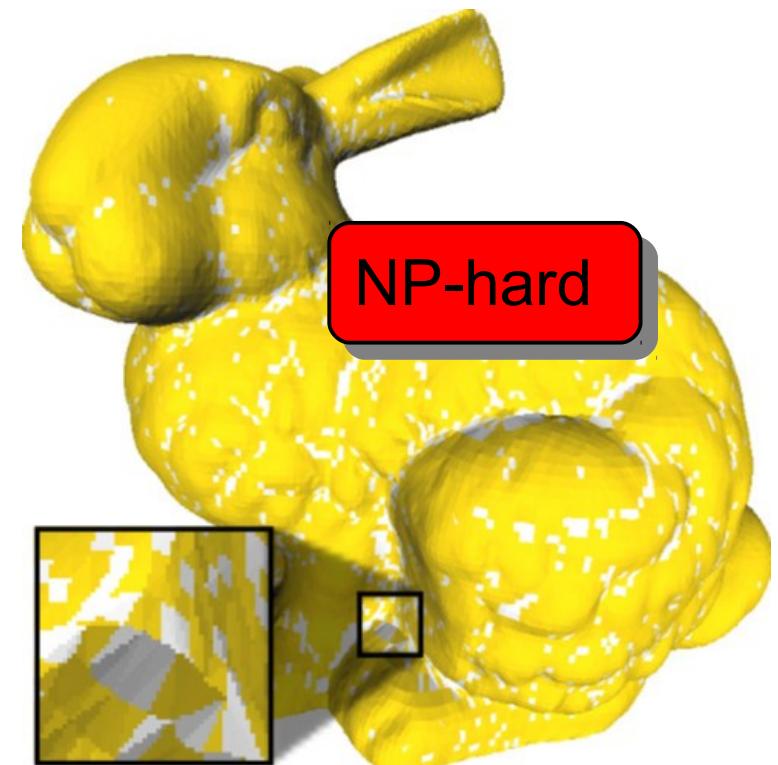


$BC_{min} : u \geq 1$

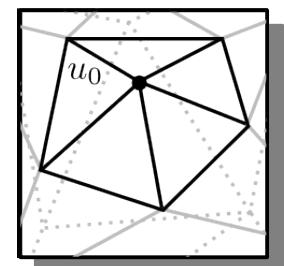


Still NP-hard?

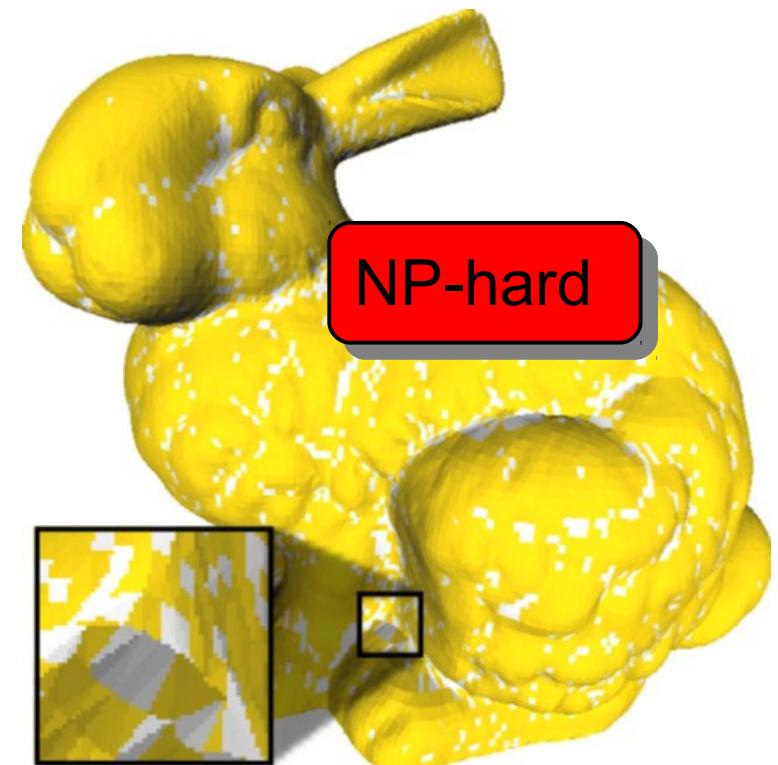
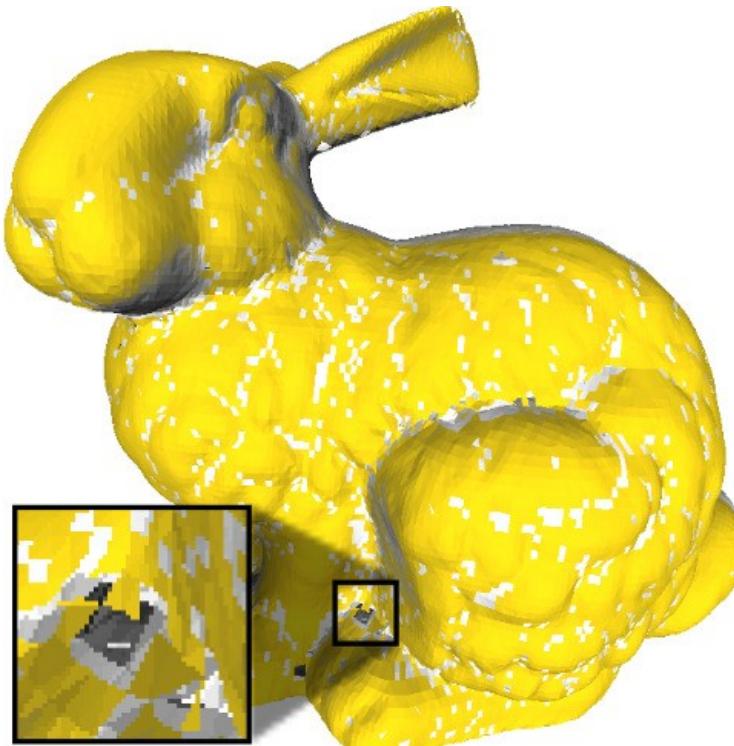
BC_0



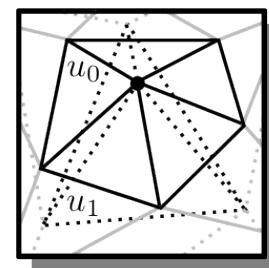
$B_{min} : u = 1$



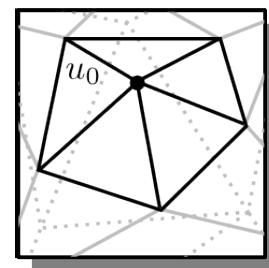
A fast Approximation



$BC_{min} : u \geq 1$



$B_{min} : u = 1$



Still NP-hard?

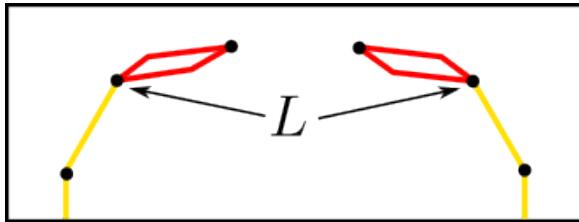
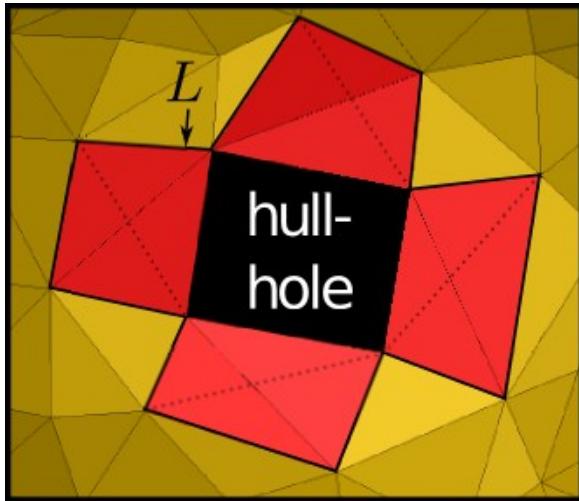
BC_0

?

B_{out}



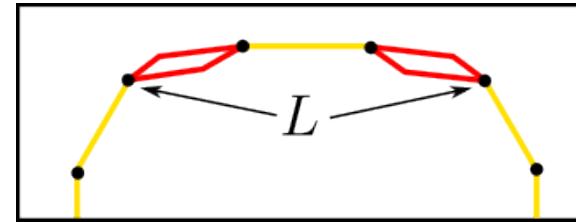
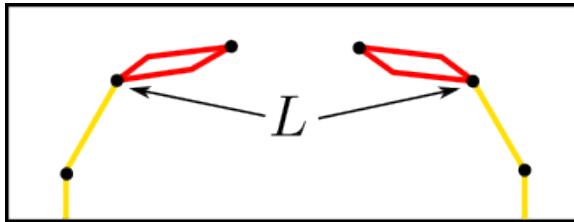
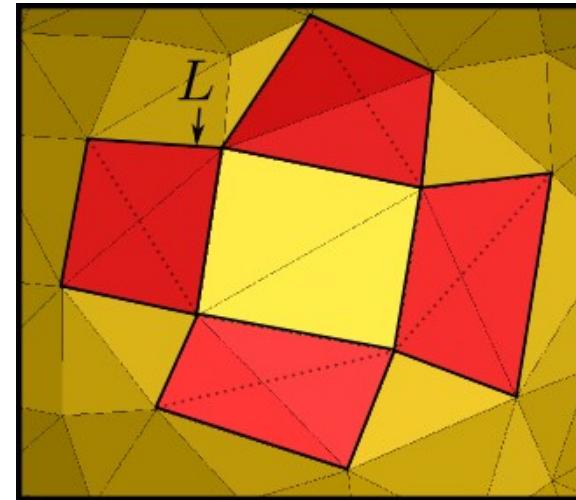
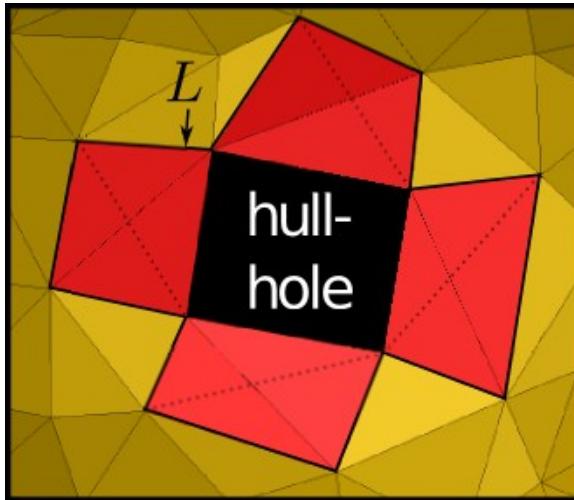
Artifact Removal



Bound artifacts



Artifact Removal

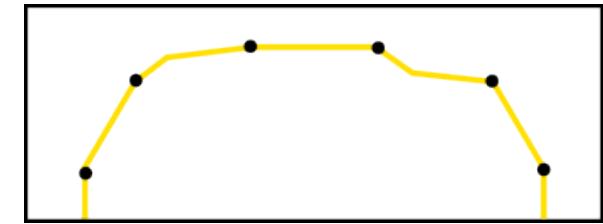
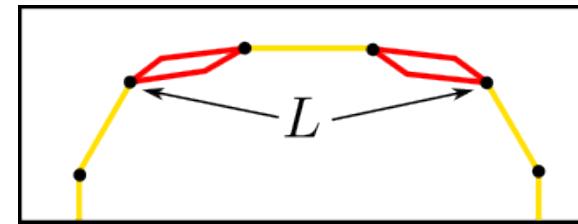
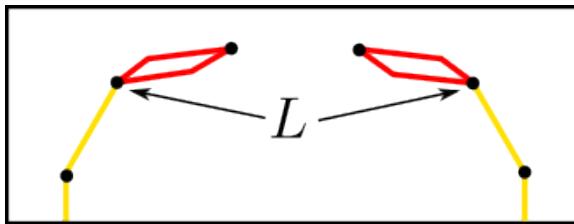
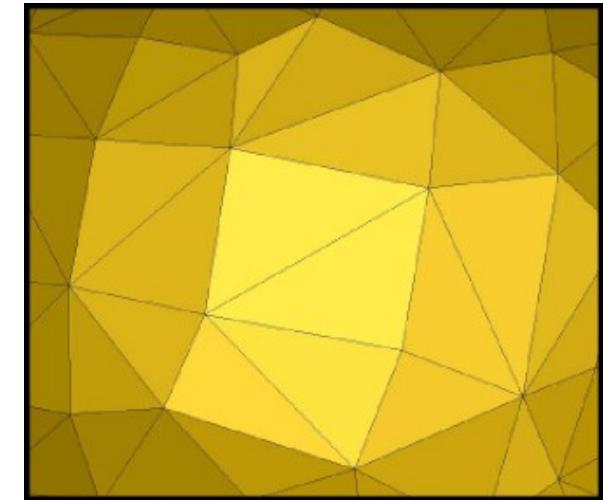
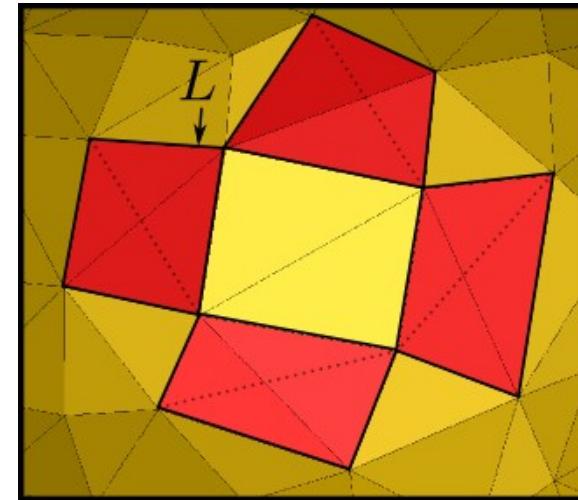
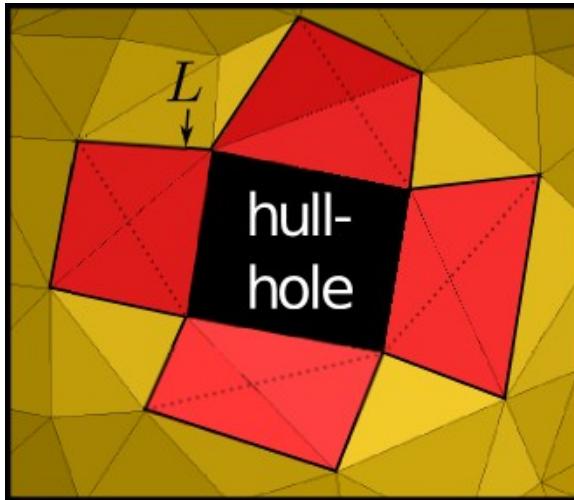


Bound artifacts

Cover hull holes



Artifact Removal



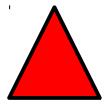
Bound artifacts

Cover hull holes

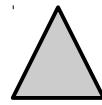
Sculpture slivers



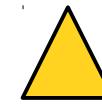
Our Method: Overview



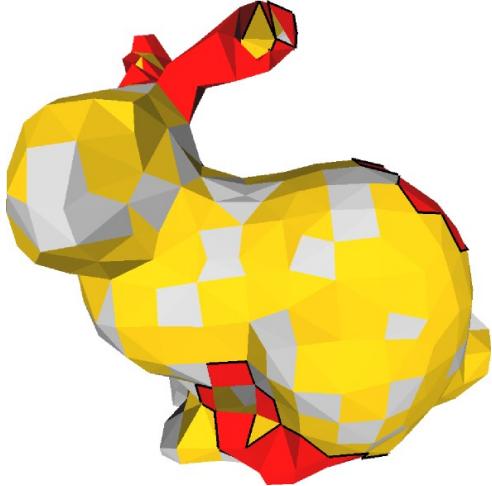
Slivers @holes



Sliver sets



manifold



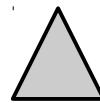
BC_0



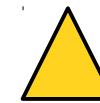
Our Method: Overview



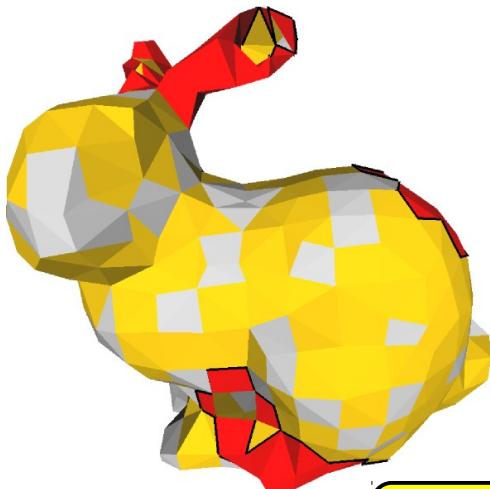
Slivers @holes



Sliver sets



manifold



BC_0

Close hull holes

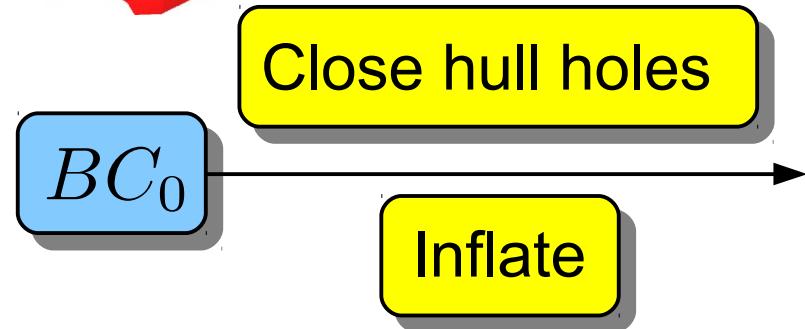
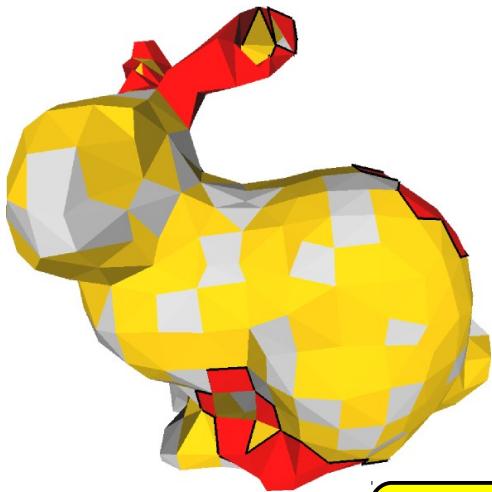


Our Method: Overview

▲ Slivers @holes

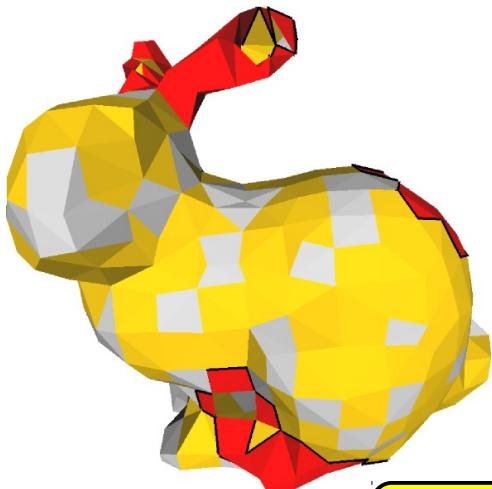
▲ Sliver sets

▲ manifold

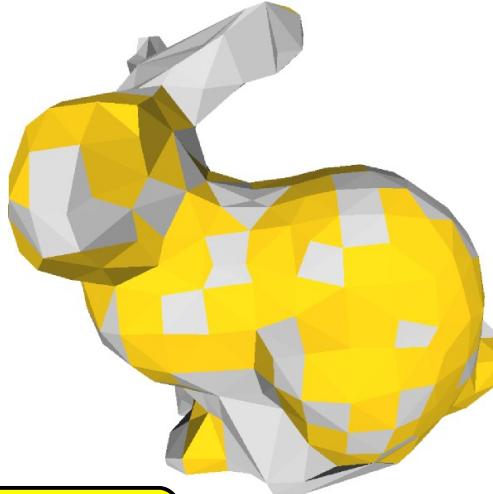


Our Method: Overview

▲ Slivers @holes



▲ Sliver sets

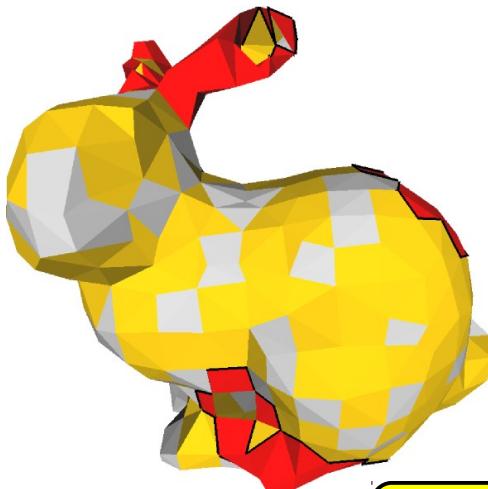


▲ manifold

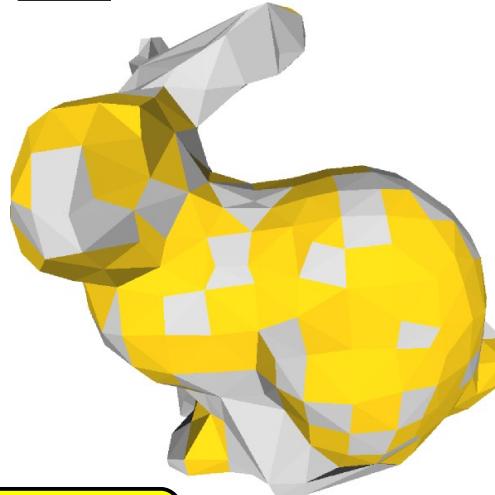


Our Method: Overview

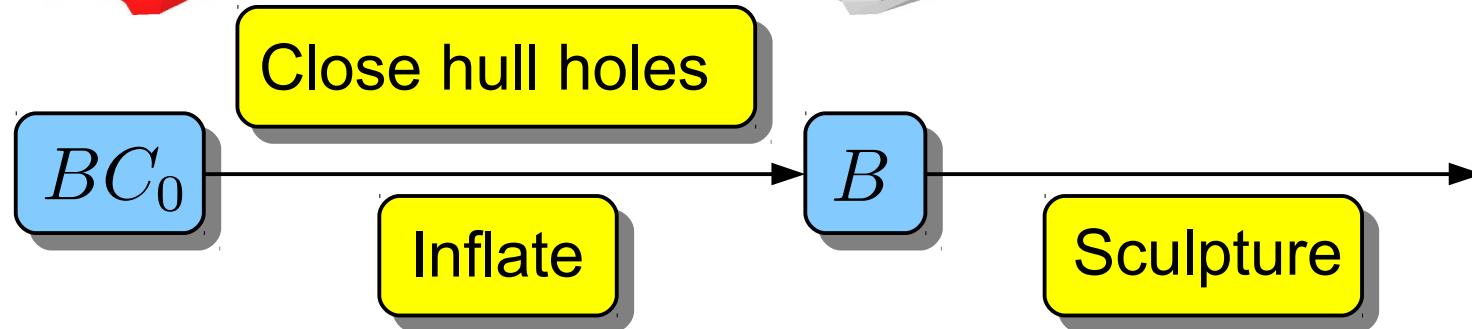
▲ Slivers @holes



▲ Sliver sets

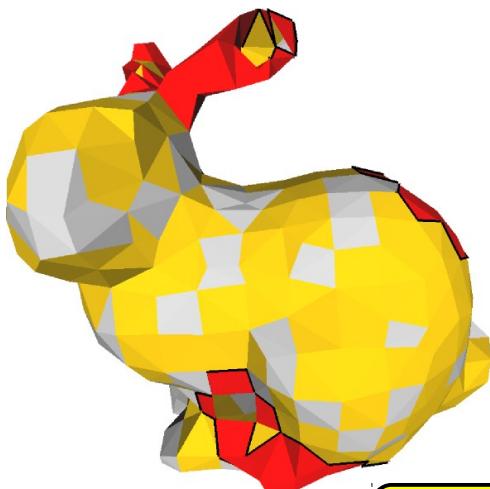


▲ manifold

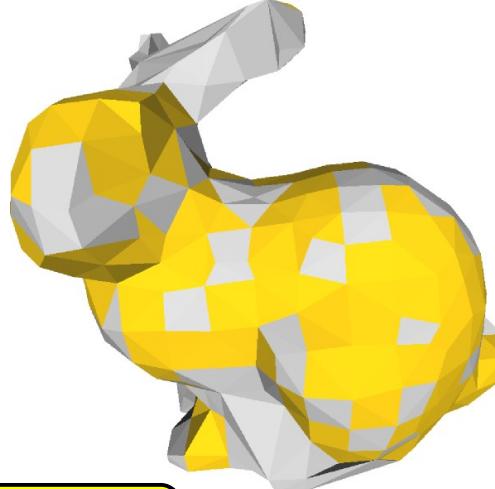


Our Method: Overview

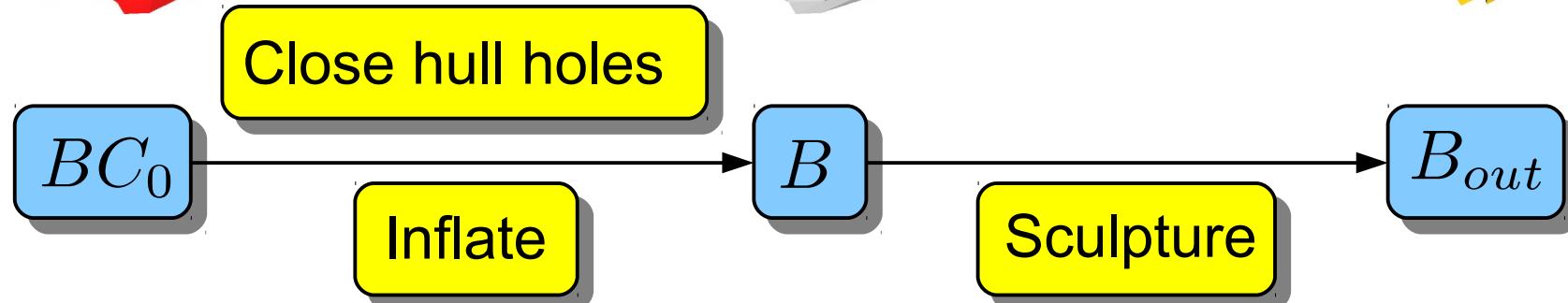
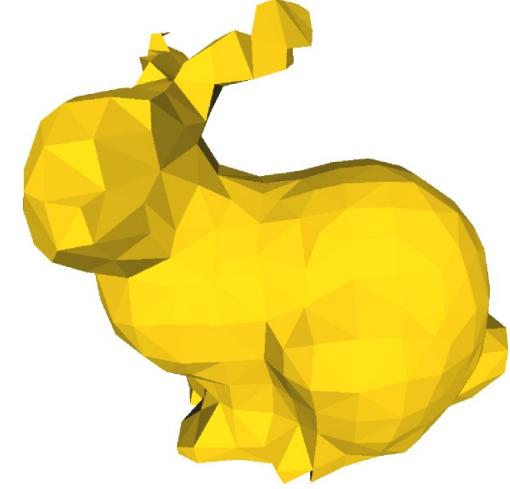
▲ Slivers @holes



▲ Sliver sets

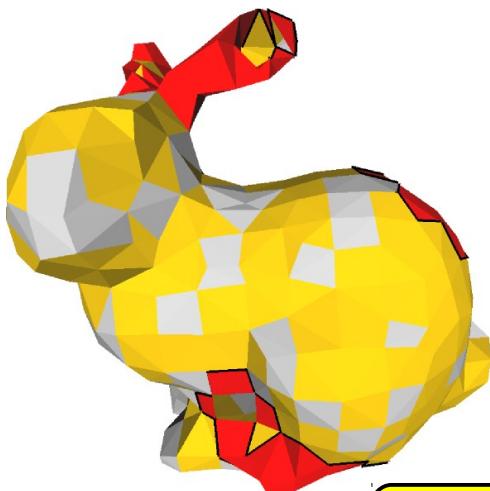


▲ manifold

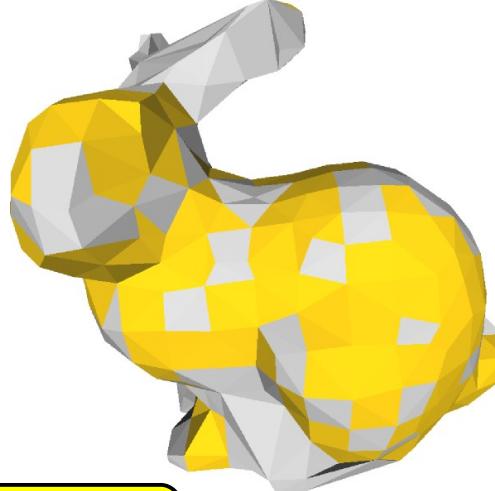


Our Method: Overview

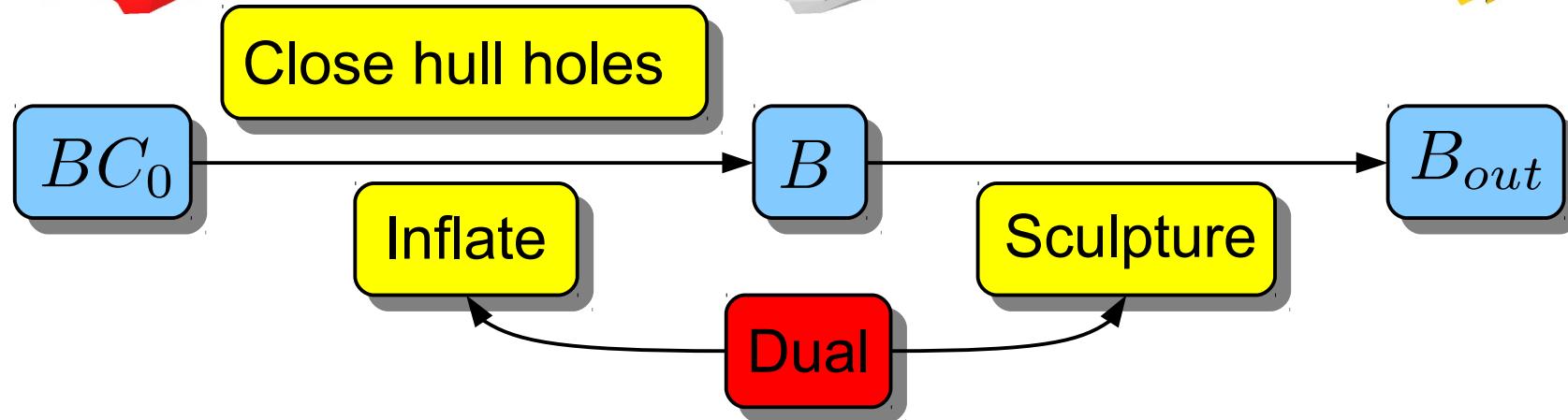
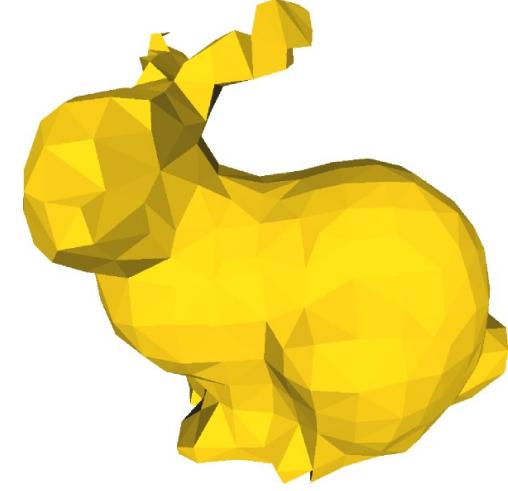
▲ Slivers @holes



▲ Sliver sets

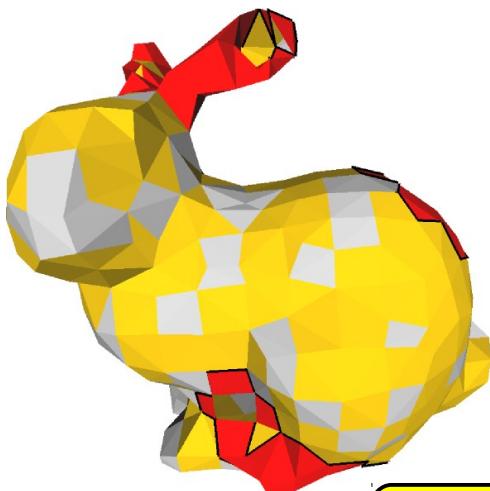


▲ manifold

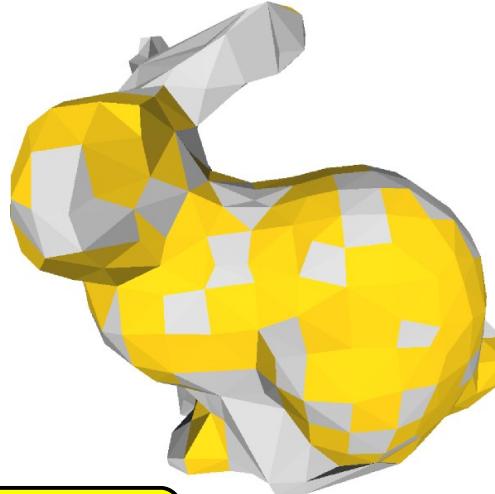


Our Method: Overview

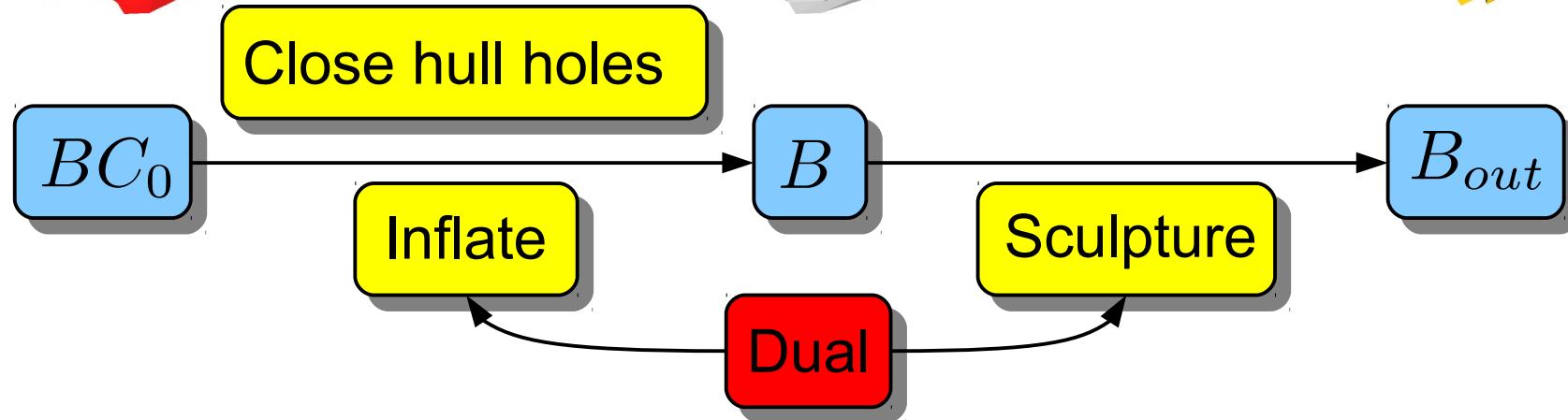
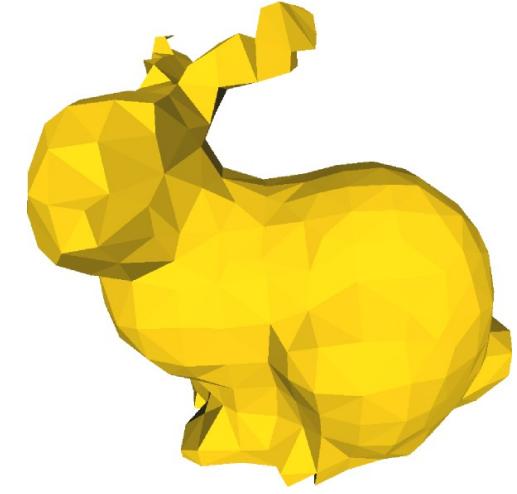
▲ Slivers @holes



▲ Sliver sets



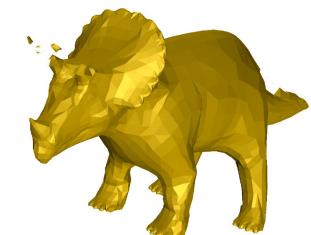
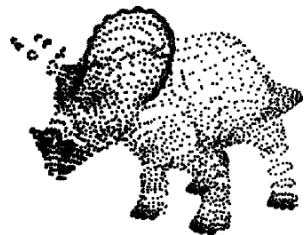
▲ manifold



Inflating exploits **Closure** to reconstruct very sparse sampling



Results (1): Very Sparse Sampling



Input

Wrap

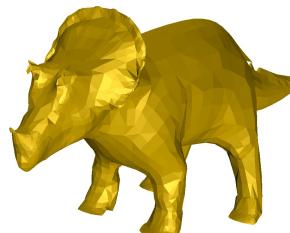
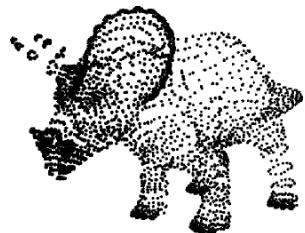
Shrink

TCocone

Ours



Results (1): Very Sparse Sampling



Empty Set



Input

Wrap

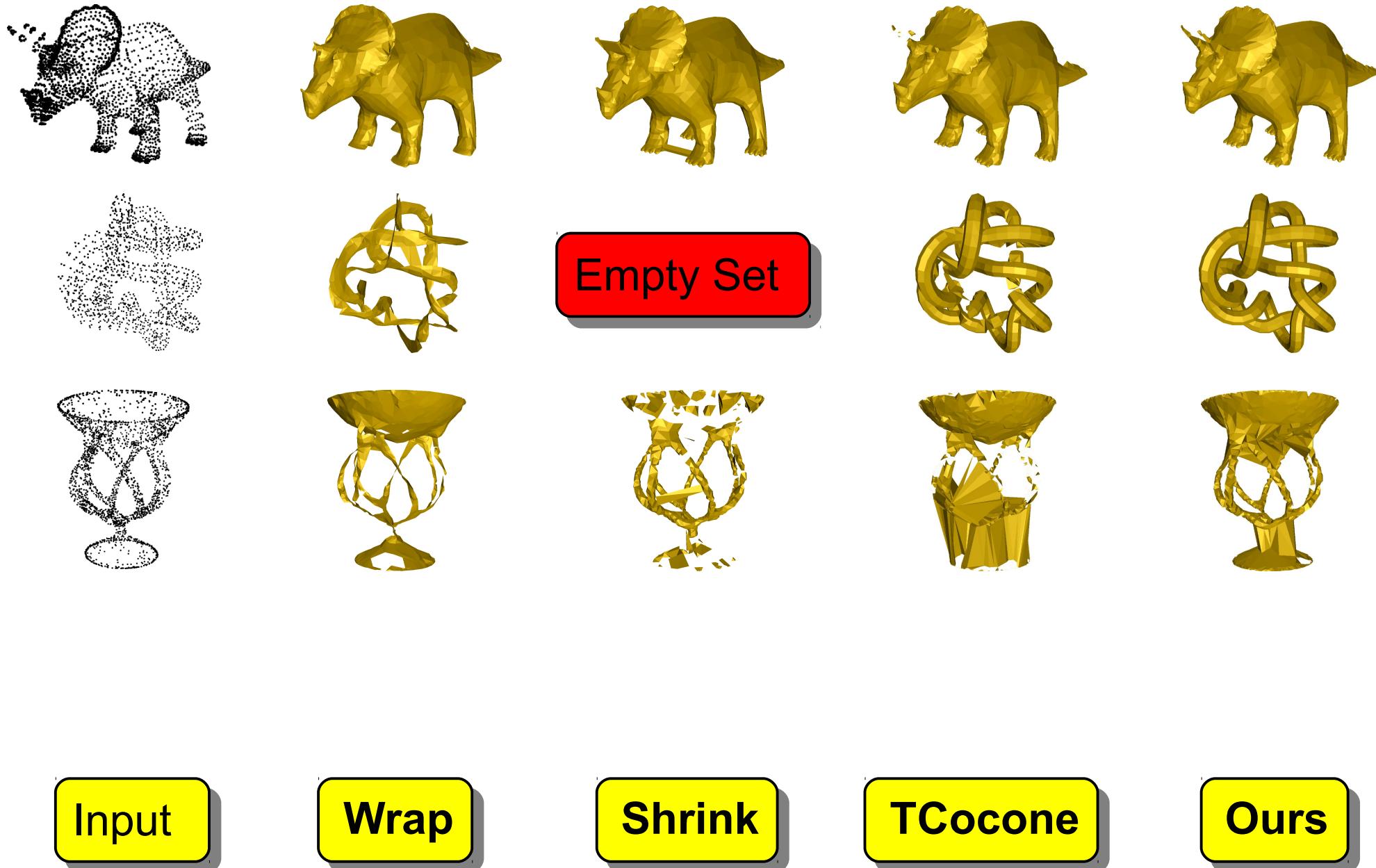
Shrink

TCocone

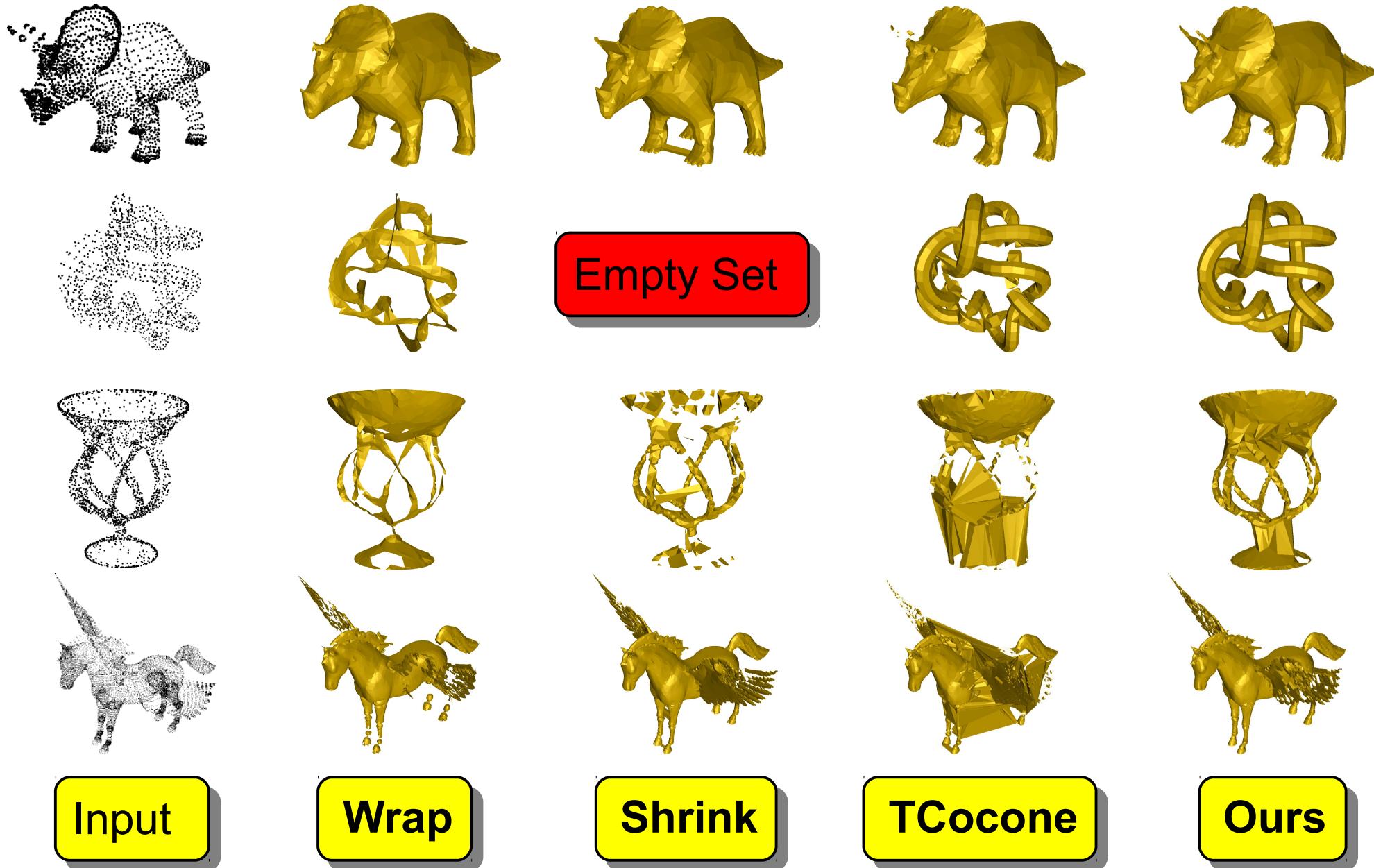
Ours



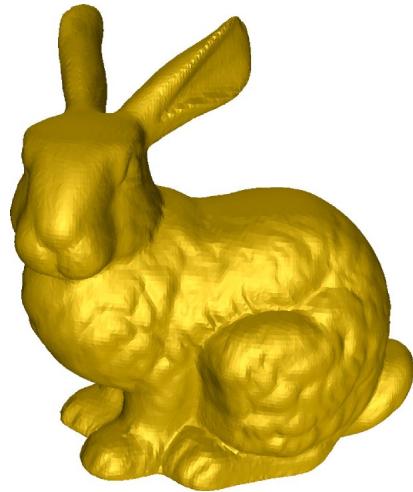
Results (1): Very Sparse Sampling



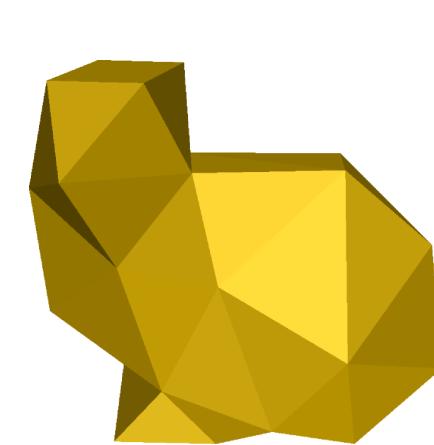
Results (1): Very Sparse Sampling



Results (2): Robust to sub-sampling



35k vertices

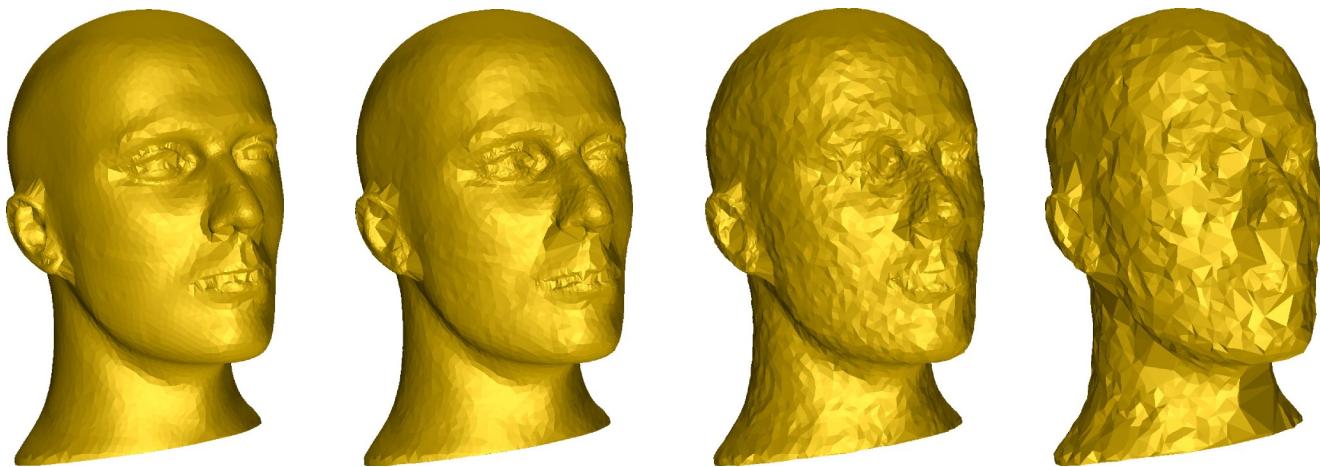


33 vertices

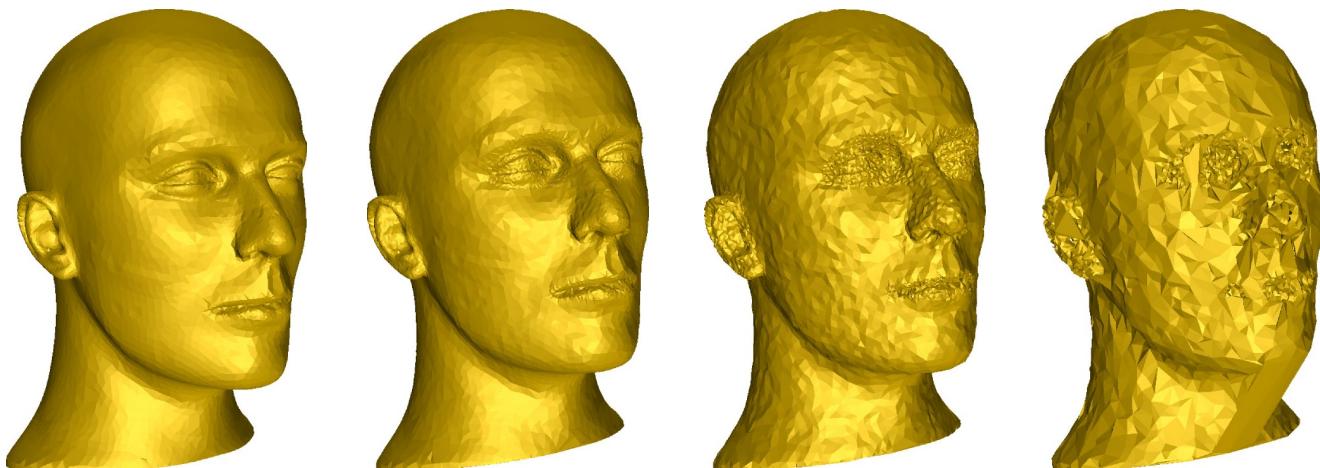


Results (3): Noise tolerant

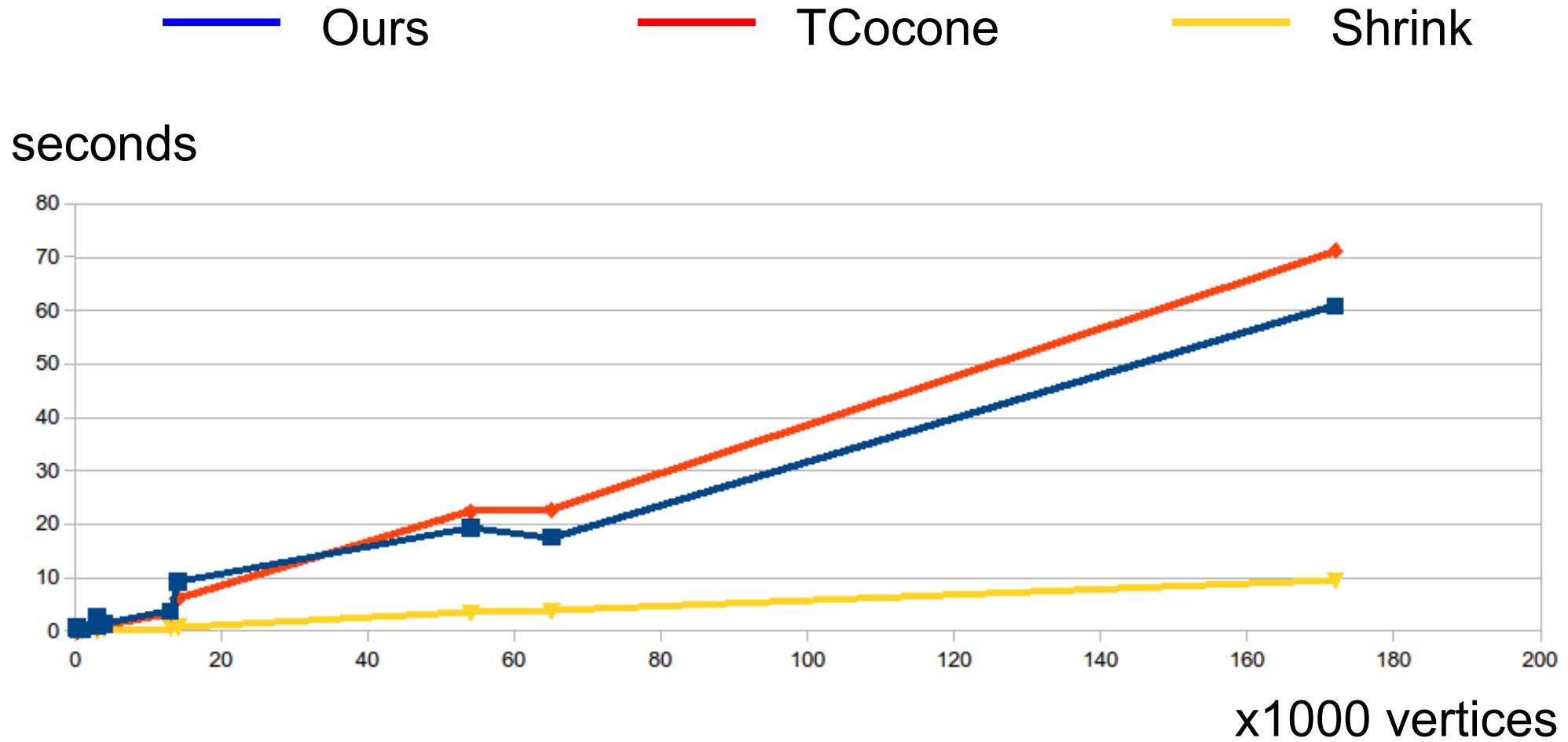
RCocone



Ours



Results (4): Runtime



Our unoptimized algorithm is competitive for global approach



Results(5): Guarantees of B_{out}

Watertight Manifold



Results(5): Guarantees of B_{out}

Watertight Manifold

1 Connected Component



Results(5): Guarantees of B_{out}

Watertight Manifold

contains P (or in interior)

1 Connected Component



Results(5): Guarantees of B_{out}

Watertight Manifold

contains P (or in interior)

1 Connected Component

Conjecture: $\varepsilon < 0.5$



Limitation



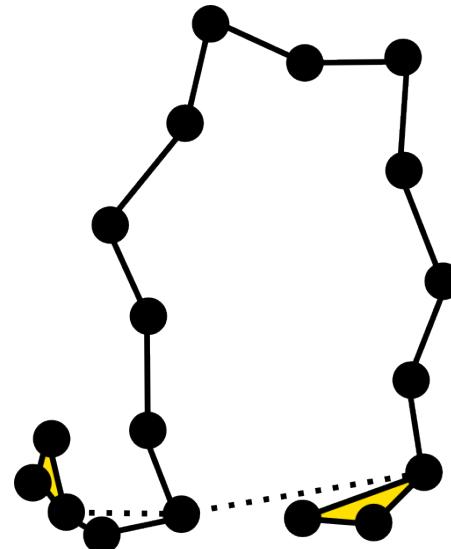
Bottom hole



Limitation



Bottom hole



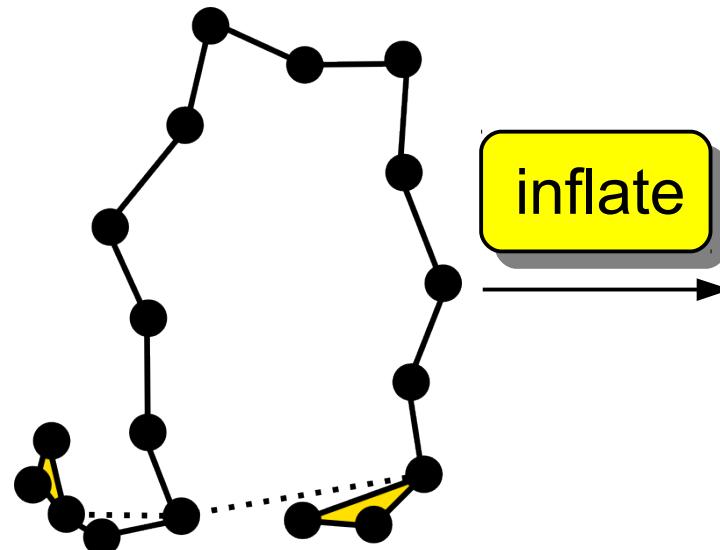
Convolved boundary



Limitation



Bottom hole



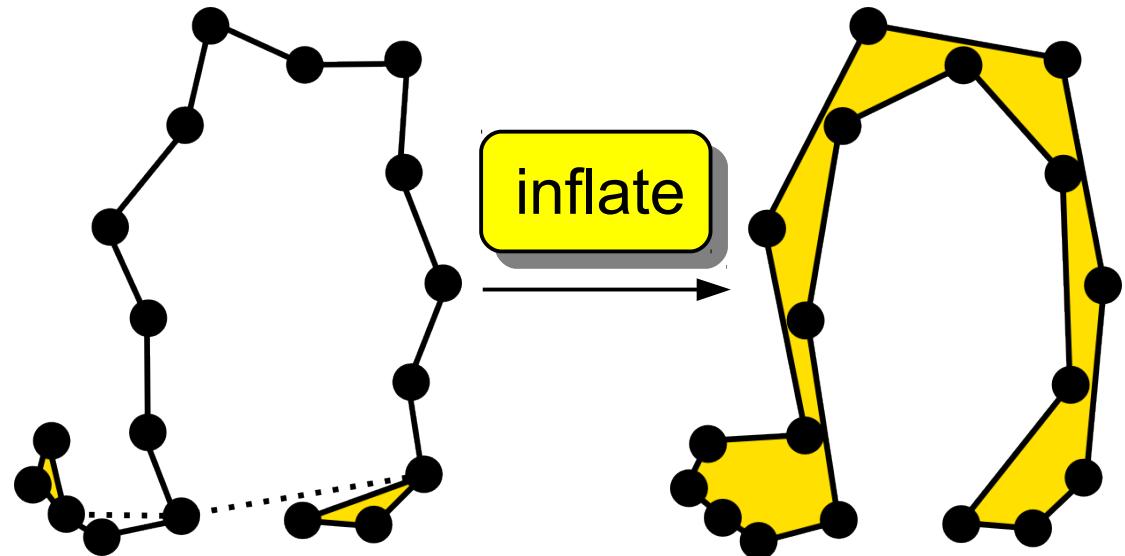
Convolved boundary



Limitation



Bottom hole



Convolved boundary

Far from B_{\min}



Close Convoluted Holes



Close Convoluted Holes

Bounded Surfaces



Future work

Close Convoluted Holes

Bounded Surfaces

Multiple Components



Future work

Close Convoluted Holes

Bounded Surfaces

Multiple Components

Local Reconstruction



Future work

Close Convoluted Holes

Proof: $\varepsilon < 0.5$

Bounded Surfaces

Multiple Components

Local Reconstruction



Future work

Close Convoluted Holes

Proof: $\varepsilon < 0.5$

Bounded Surfaces

Exact B_{min} for $\varepsilon < 0.5$

Multiple Components

Local Reconstruction



Future work

Close Convoluted Holes

Proof: $\varepsilon < 0.5$

Bounded Surfaces

Exact B_{min} for $\varepsilon < 0.5$

Multiple Components

Noisy Samples

Local Reconstruction



Future work

Close Convoluted Holes

Proof: $\varepsilon < 0.5$

Bounded Surfaces

Exact B_{min} for $\varepsilon < 0.5$

Multiple Components

Noisy Samples

Local Reconstruction

Use Prior Knowledge



Contributions

Source: <http://sf.net/p/connect3d/>



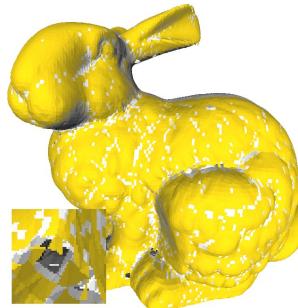
$$B_{min} = \operatorname{argmin}_{B \in \mathbf{B}} \sum_{t \in B} \lambda(t)$$



Contributions

Source: <http://sf.net/p/connect3d/>

$$B_{min} = \operatorname{argmin}_{B \in \mathbf{B}} \sum_{t \in B} \lambda(t)$$



$BC_0 \rightarrow$ Visualizes shape



Contributions

Source: <http://sf.net/p/connect3d/>

$$B_{min} = \operatorname{argmin}_{B \in \mathbf{B}} \sum_{t \in B} \lambda(t)$$



$BC_0 \rightarrow$ Visualizes shape

Topolog. operations $\rightarrow B_{out}$



$$B_{min} = \operatorname{argmin}_{B \in \mathbf{B}} \sum_{t \in B} \lambda(t)$$



$BC_0 \rightarrow$ Visualizes shape

Topolog. operations $\rightarrow B_{out}$

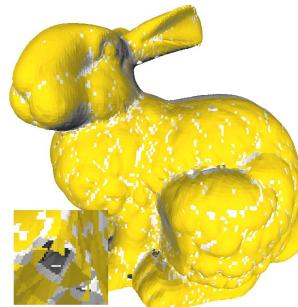
Closure \rightarrow Sparse features



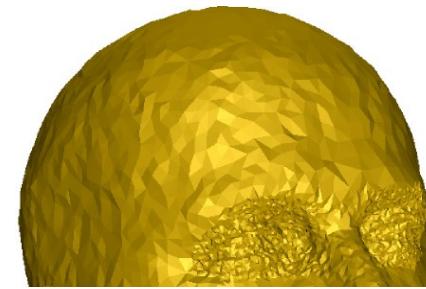
Contributions

Source: <http://sf.net/p/connect3d/>

$$B_{min} = \operatorname{argmin}_{B \in \mathbf{B}} \sum_{t \in B} \lambda(t)$$



$BC_0 \rightarrow$ Visualizes shape



Noise tolerant

Topolog. operations $\rightarrow B_{out}$

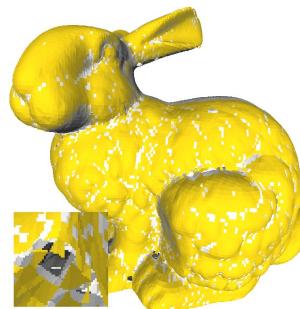
Closure \rightarrow Sparse features



Contributions

Source: <http://sf.net/p/connect3d/>

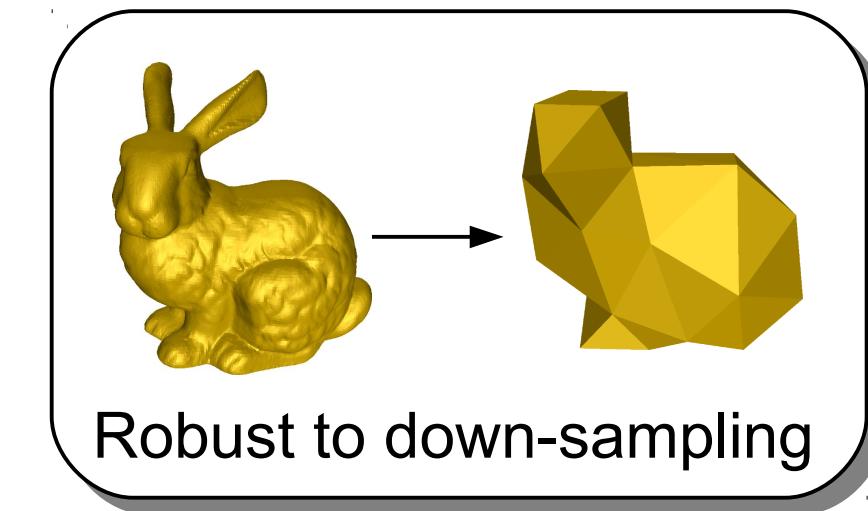
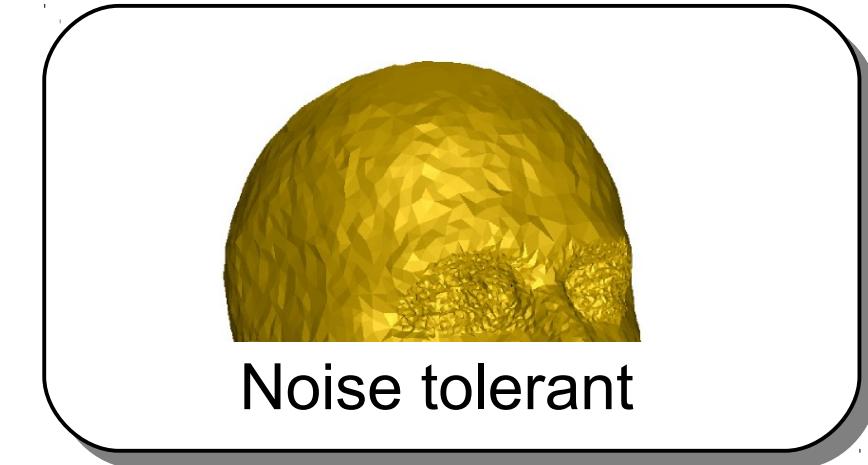
$$B_{min} = \operatorname{argmin}_{B \in \mathbf{B}} \sum_{t \in B} \lambda(t)$$



$BC_0 \rightarrow$ Visualizes shape

Topolog. operations $\rightarrow B_{out}$

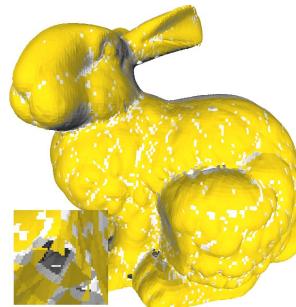
Closure \rightarrow Sparse features



Contributions

Source: <http://sf.net/p/connect3d/>

$$B_{min} = \operatorname{argmin}_{B \in \mathbf{B}} \sum_{t \in B} \lambda(t)$$



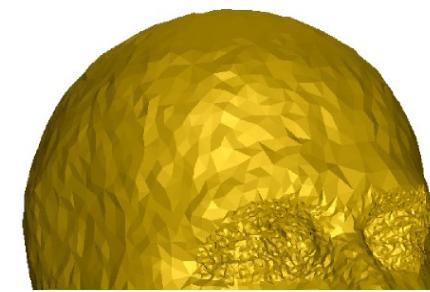
$BC_0 \rightarrow$ Visualizes shape

Topolog. operations $\rightarrow B_{out}$

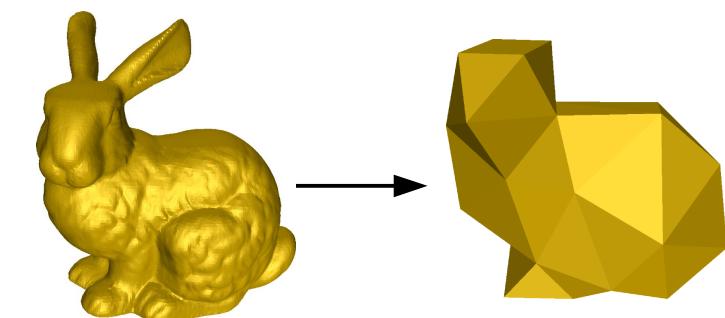
Closure \rightarrow Sparse features



+MeshLab plug-in



Noise tolerant



Robust to down-sampling

