Occluder Simplification using Planar Sections

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Coping with Scene Complexity

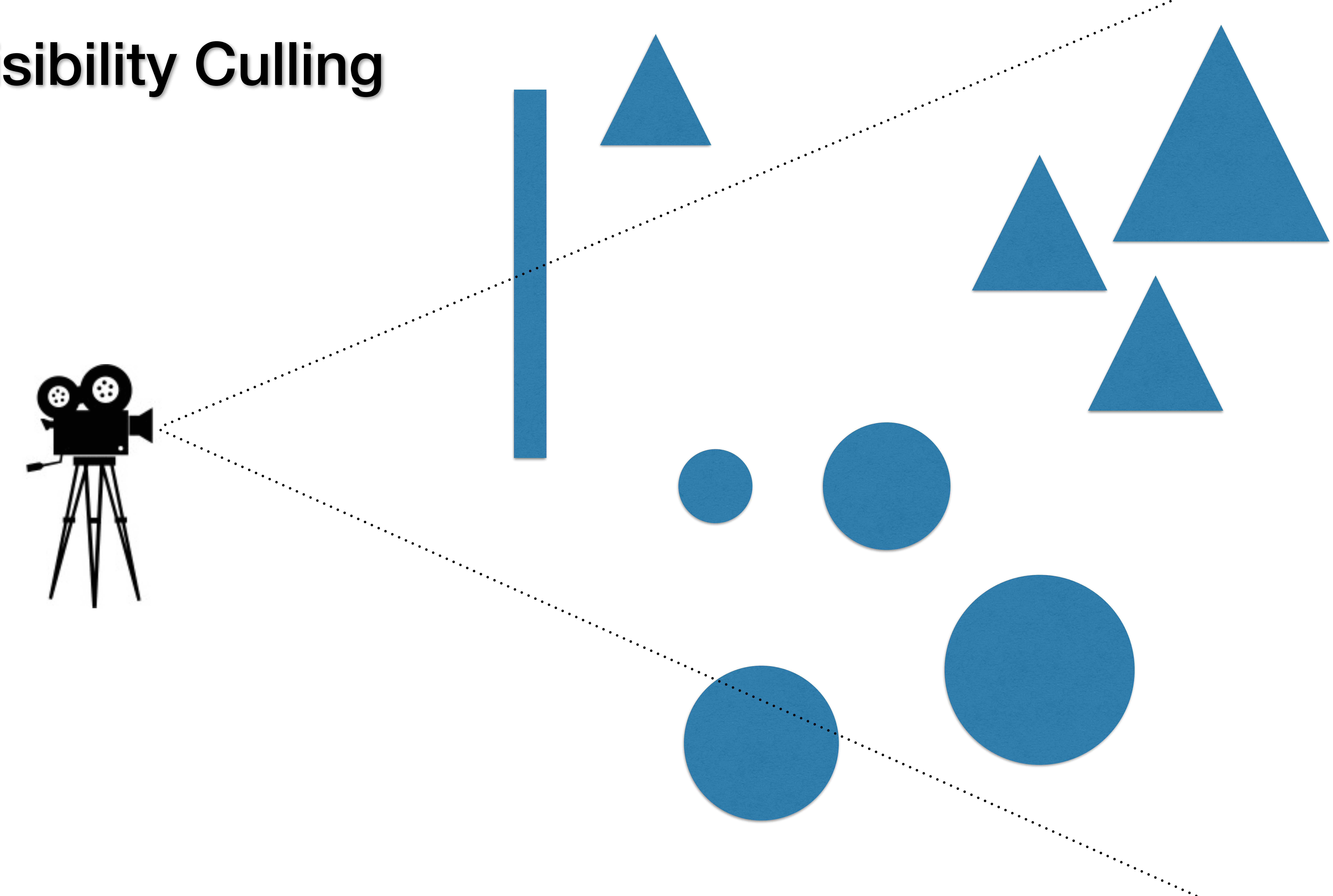
We want to render **more than we can afford**

Coping with Scene Complexity

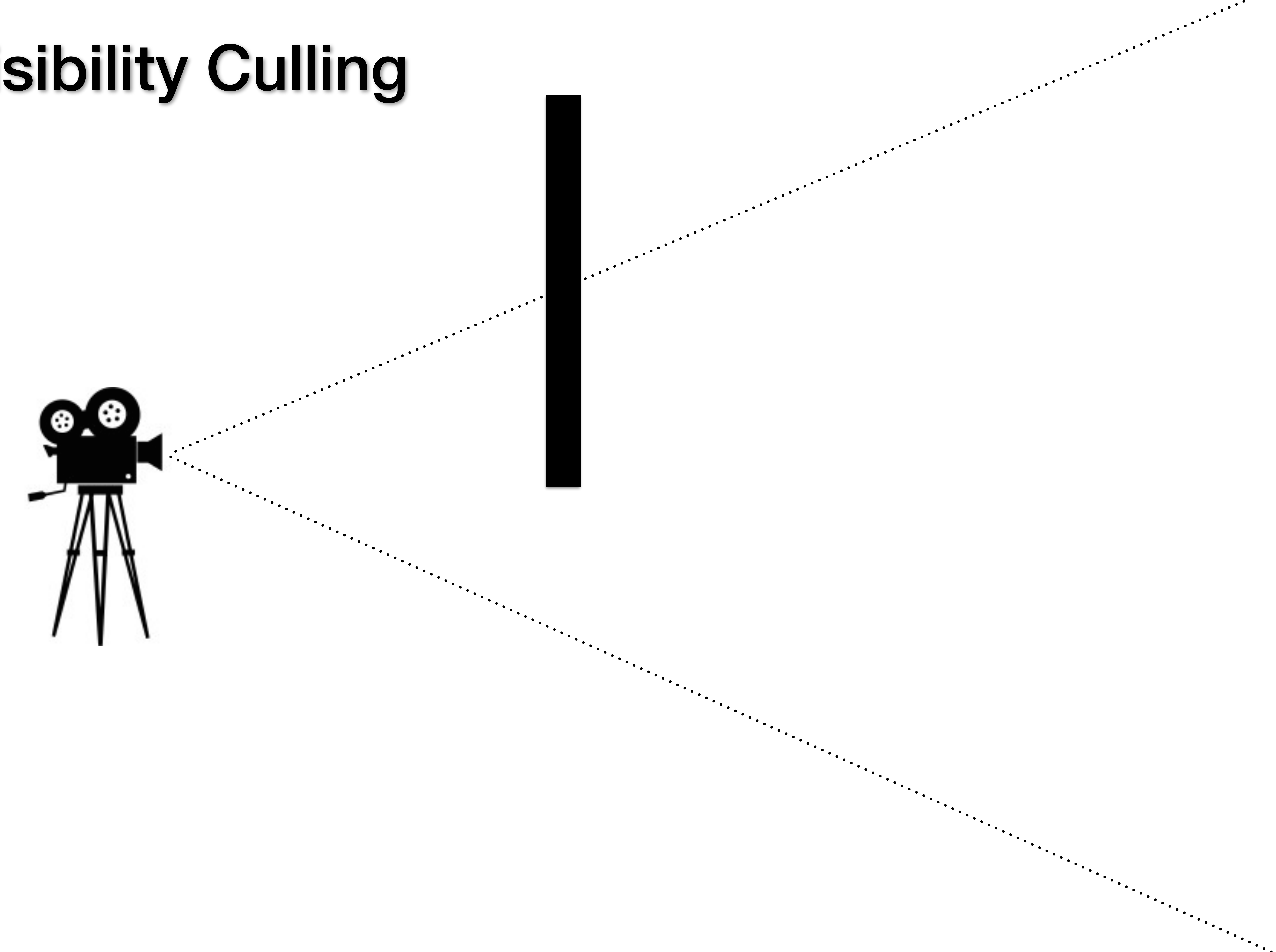
We want to render **more than we can afford**

Need to use **visibility culling** and **level-of-detail techniques**

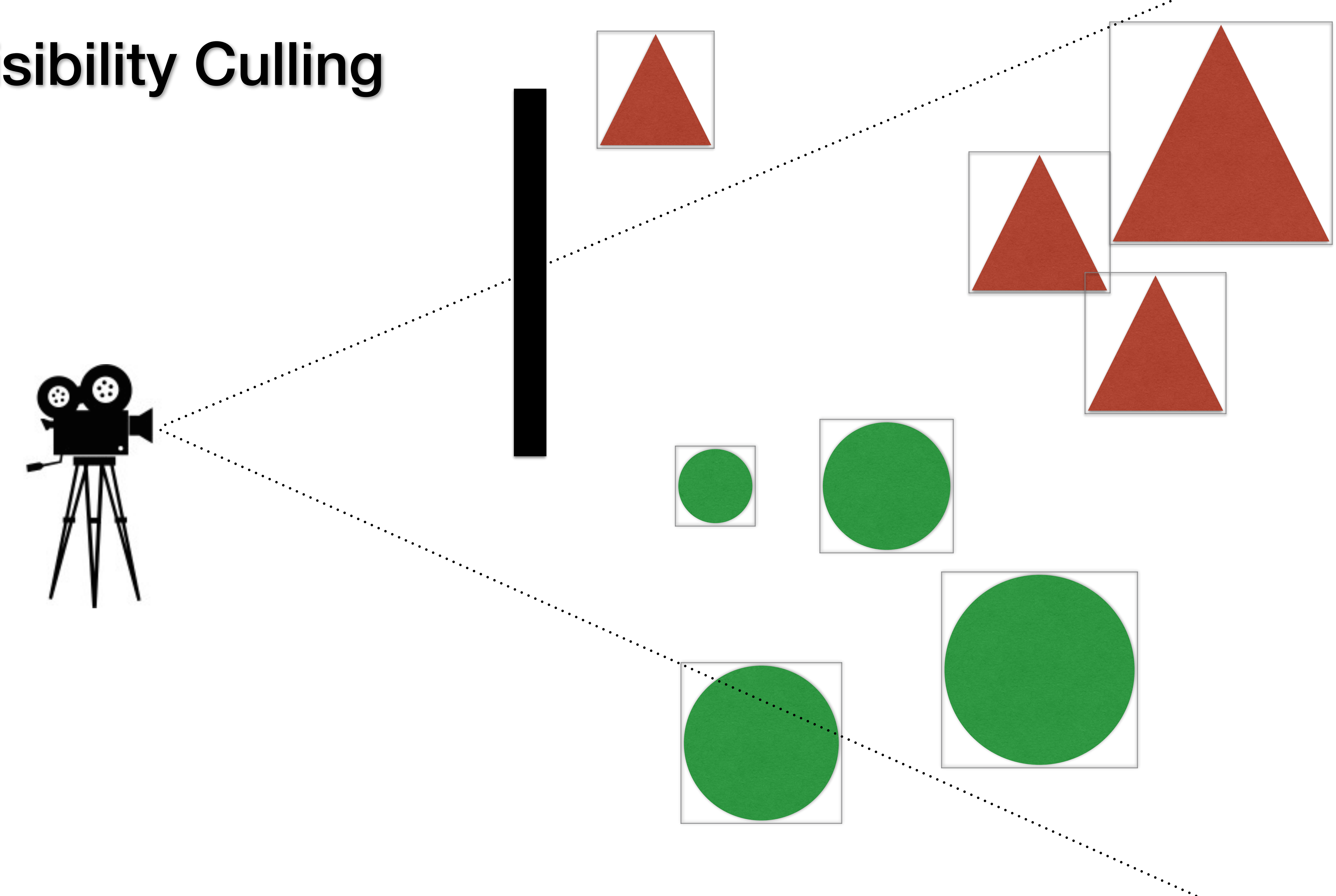
Visibility Culling



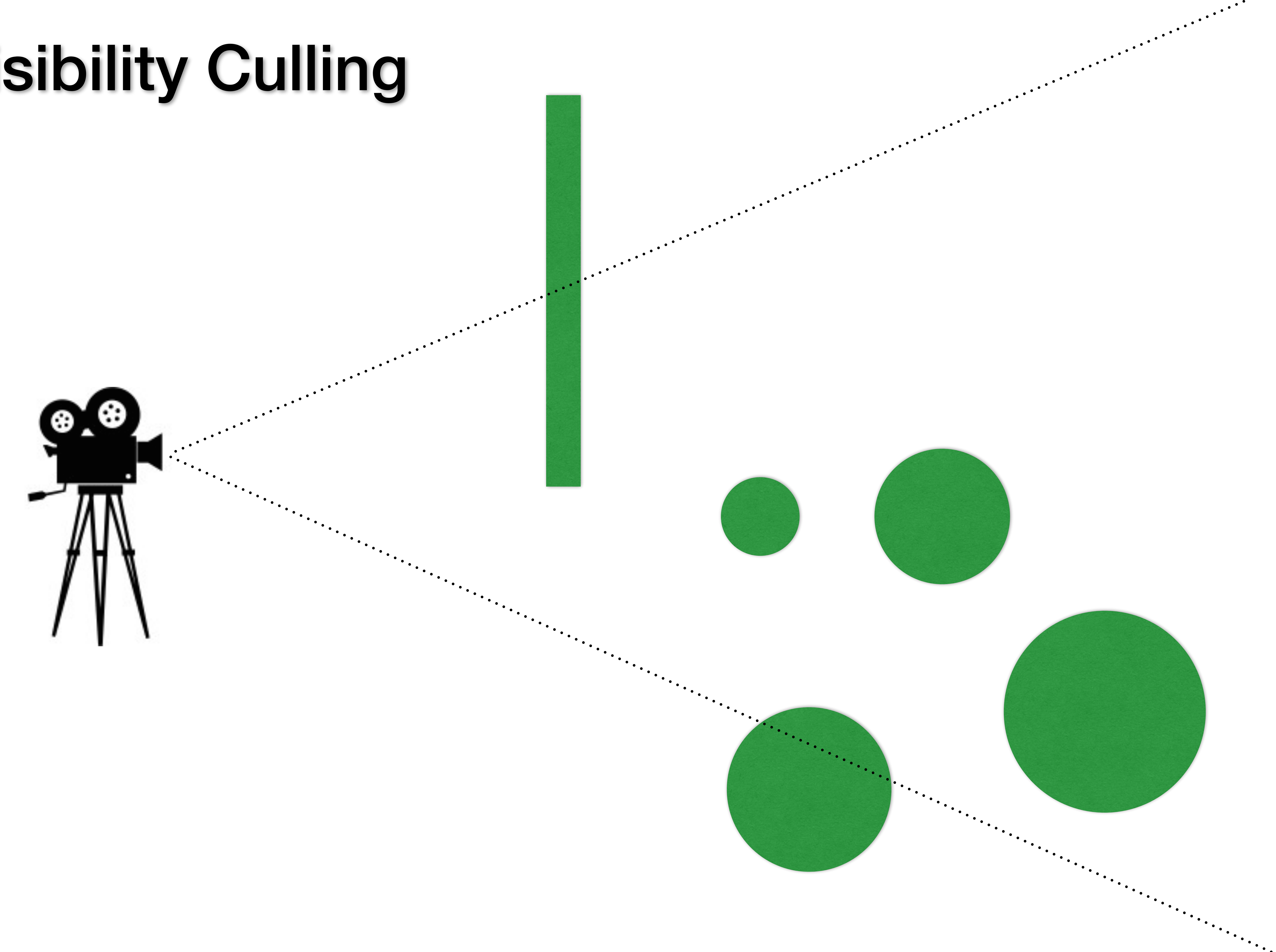
Visibility Culling



Visibility Culling



Visibility Culling



Problem

Visibility algorithm needs to be **faster** than processing the whole scene

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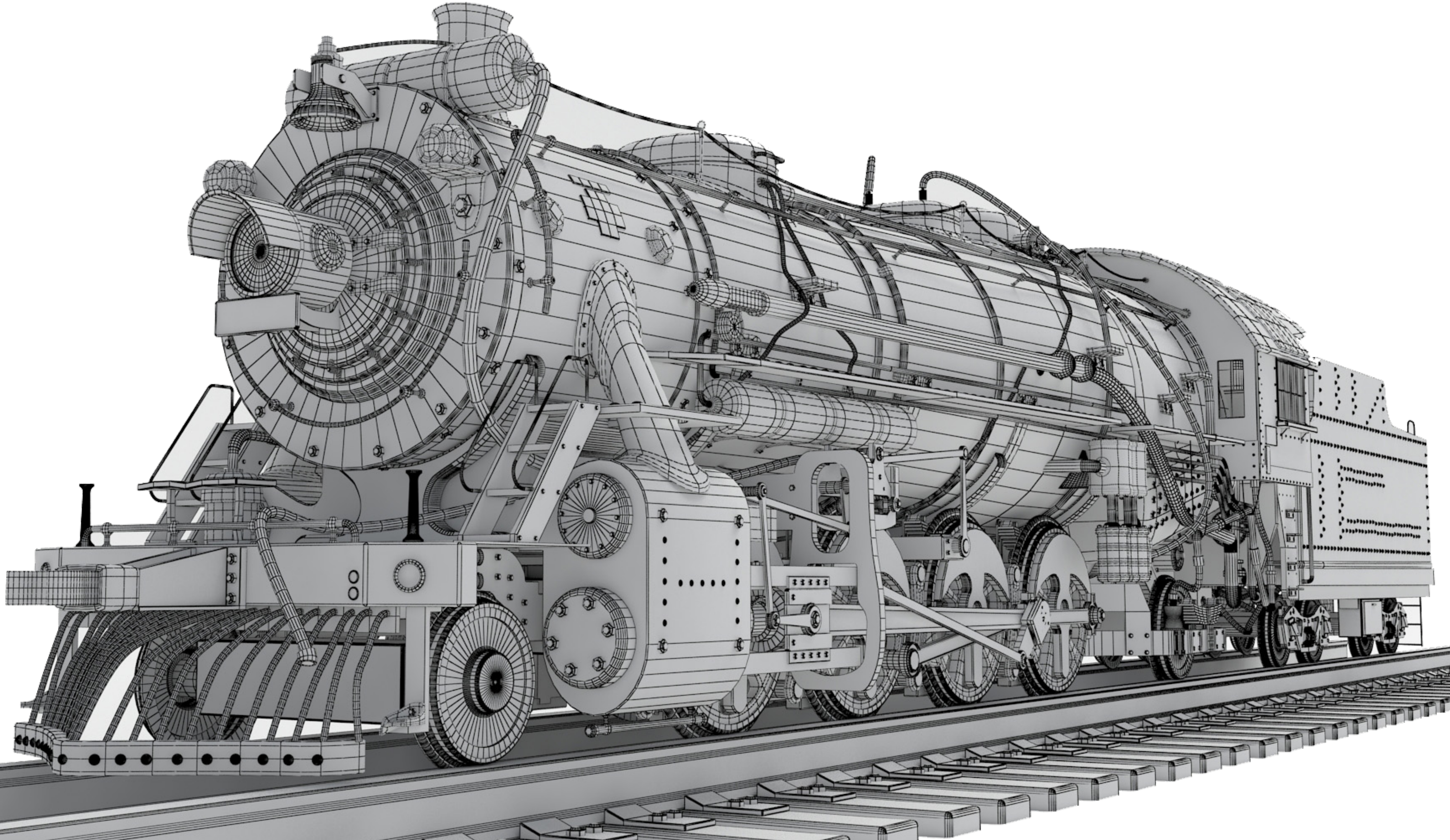
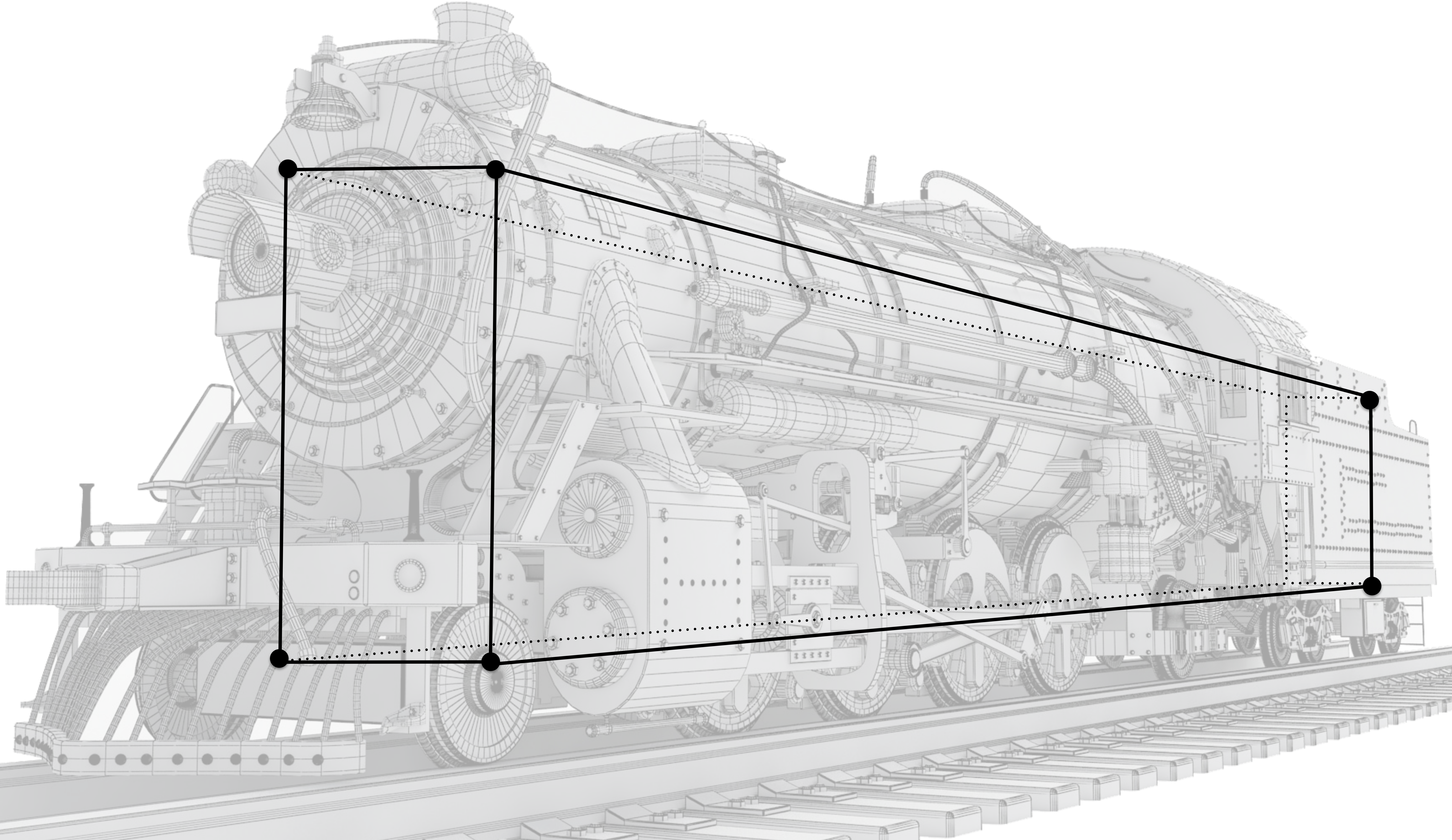
Visibility algorithm needs to be faster than processing the whole scene

Need simplified occluders; currently mostly **manual** work



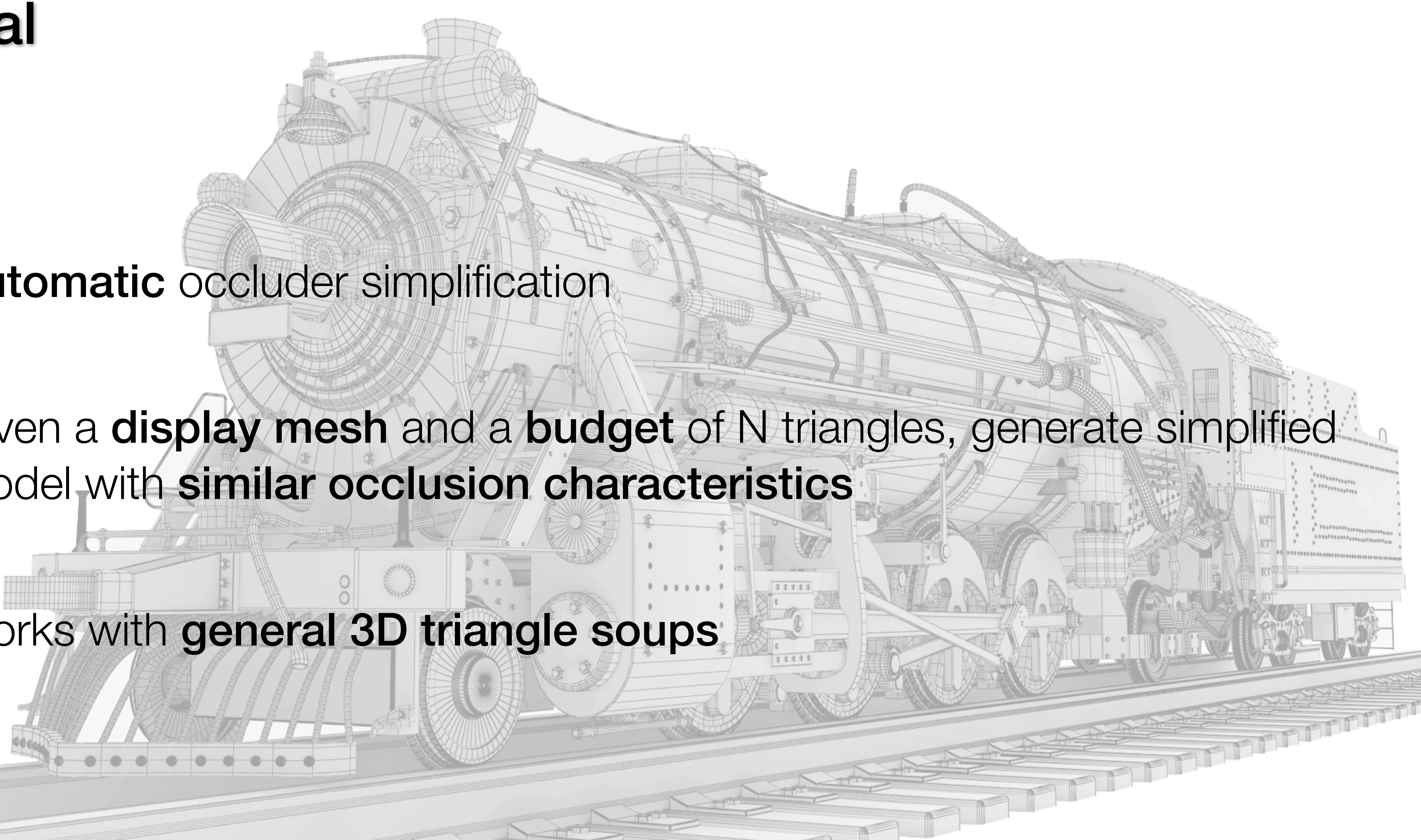


Goal

Automatic occluder simplification

Given a **display mesh** and a **budget** of N triangles, generate simplified model with **similar occlusion characteristics**

Goal



Automatic occluder simplification

Given a **display mesh** and a **budget** of N triangles, generate simplified model with **similar occlusion characteristics**

Works with **general 3D triangle soups**

Previous Work

Special cases for occlusion

- Subset of the input [Coorg and Teller 1997], [Wonka and Schmalstieg1999]
- 2.5D urban scenes [Germs and Jensen 2001]
- Valid from small region only (e.g., hoops) [Brunet 2001]
- Simple, axis-aligned 3D scenes [Darnell 2011]

Difficult to **generalize**

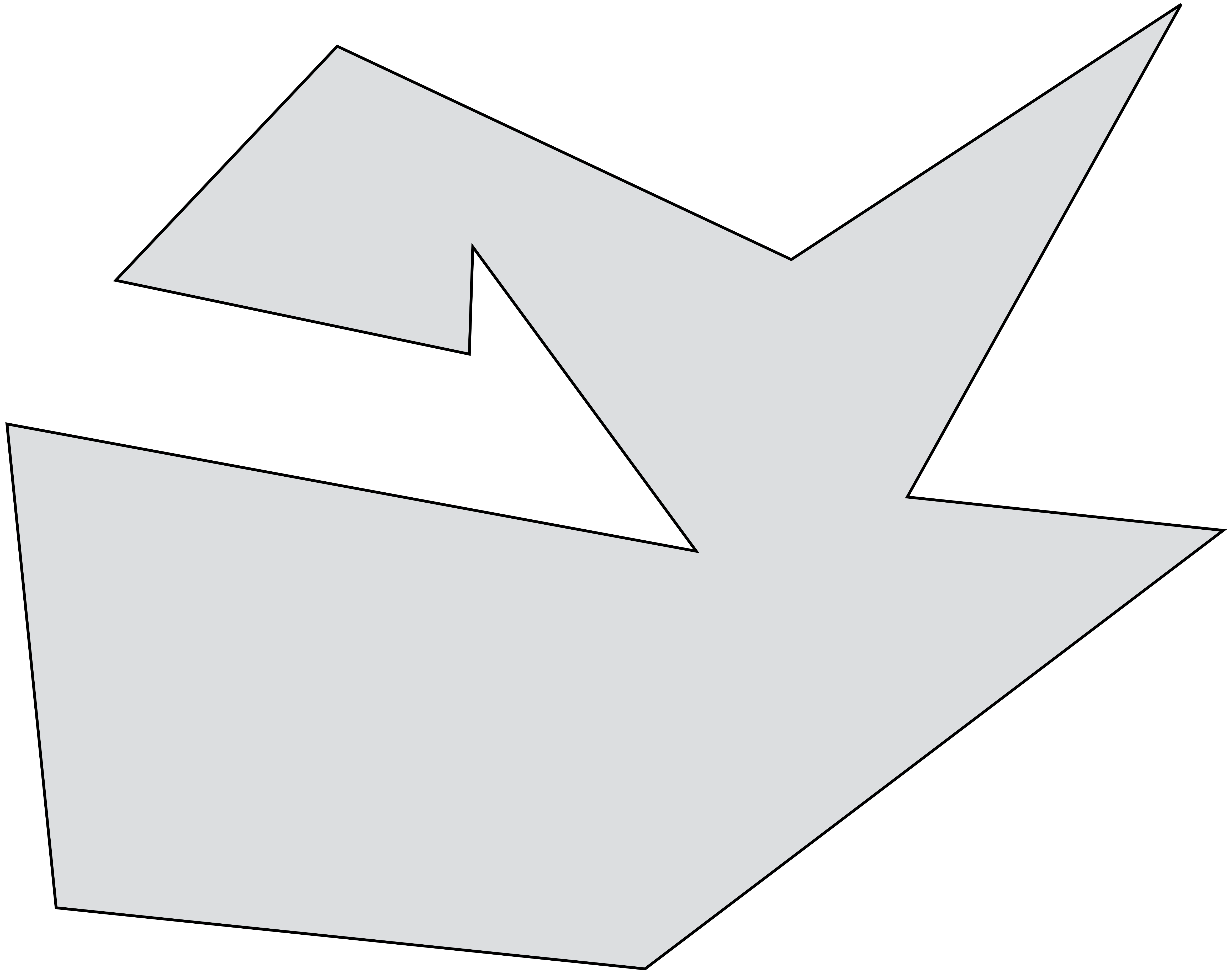
Previous Work

General mesh simplification methods

- Simplification envelopes [Cohen 1996]
- Quadratic error metrics [Garland and Heckbert 1997]
- Voxel-based [Nooruddin and Turk 2003]
- Textured tangent planes [Decoret 2003]

Focus on **visual similarity** which is not the same as occlusion

Main Idea: Focus on Occlusion



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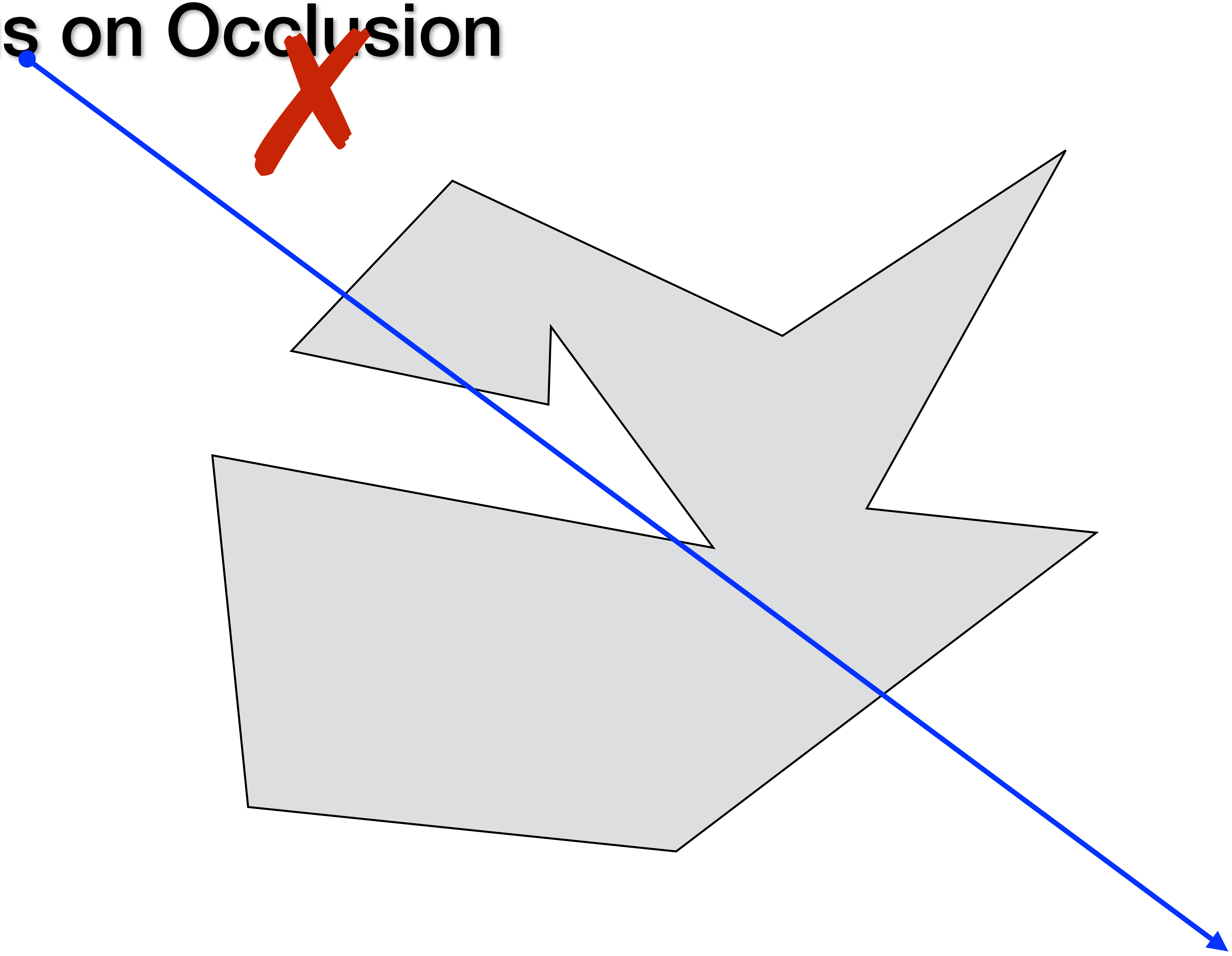

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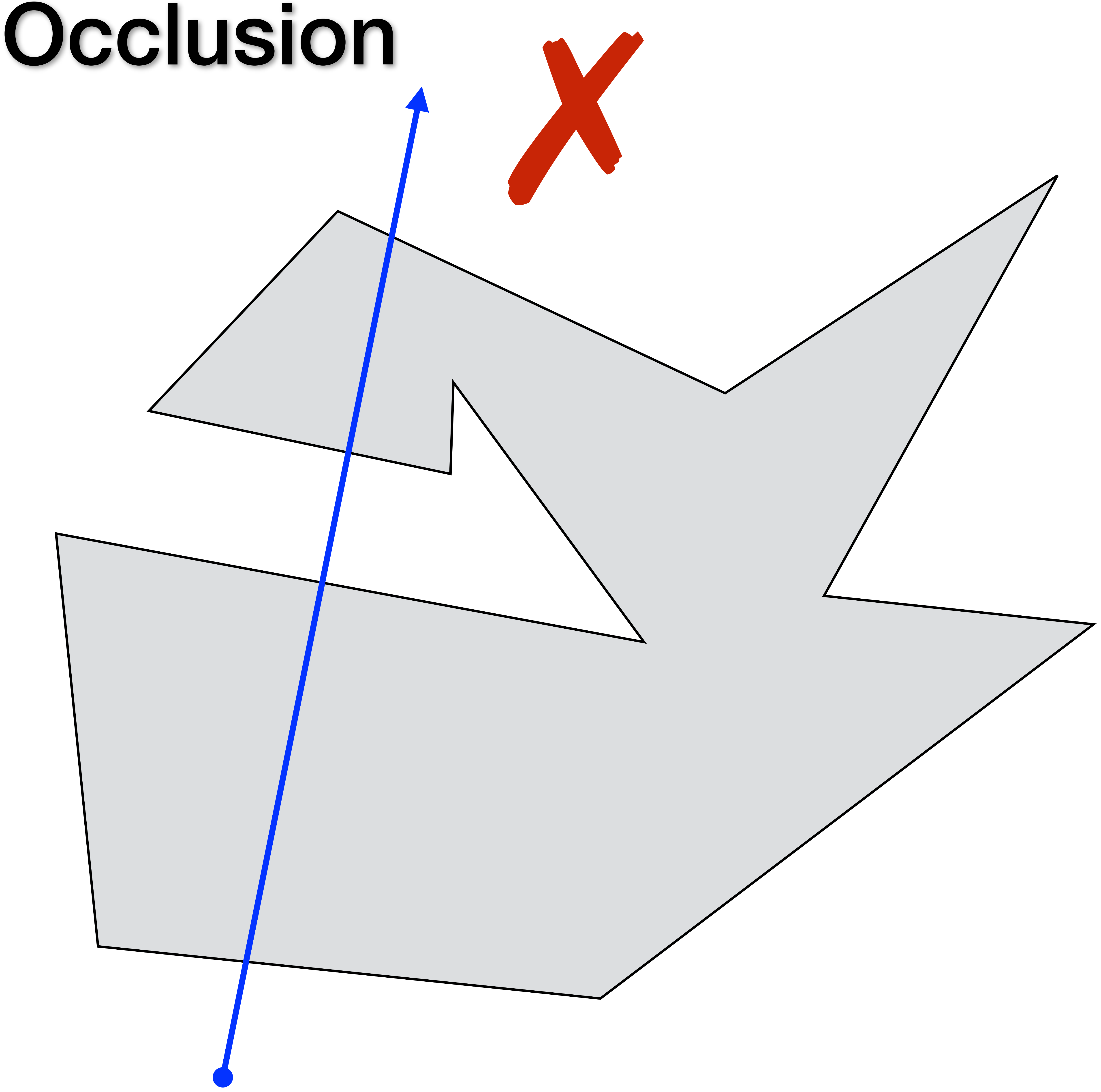

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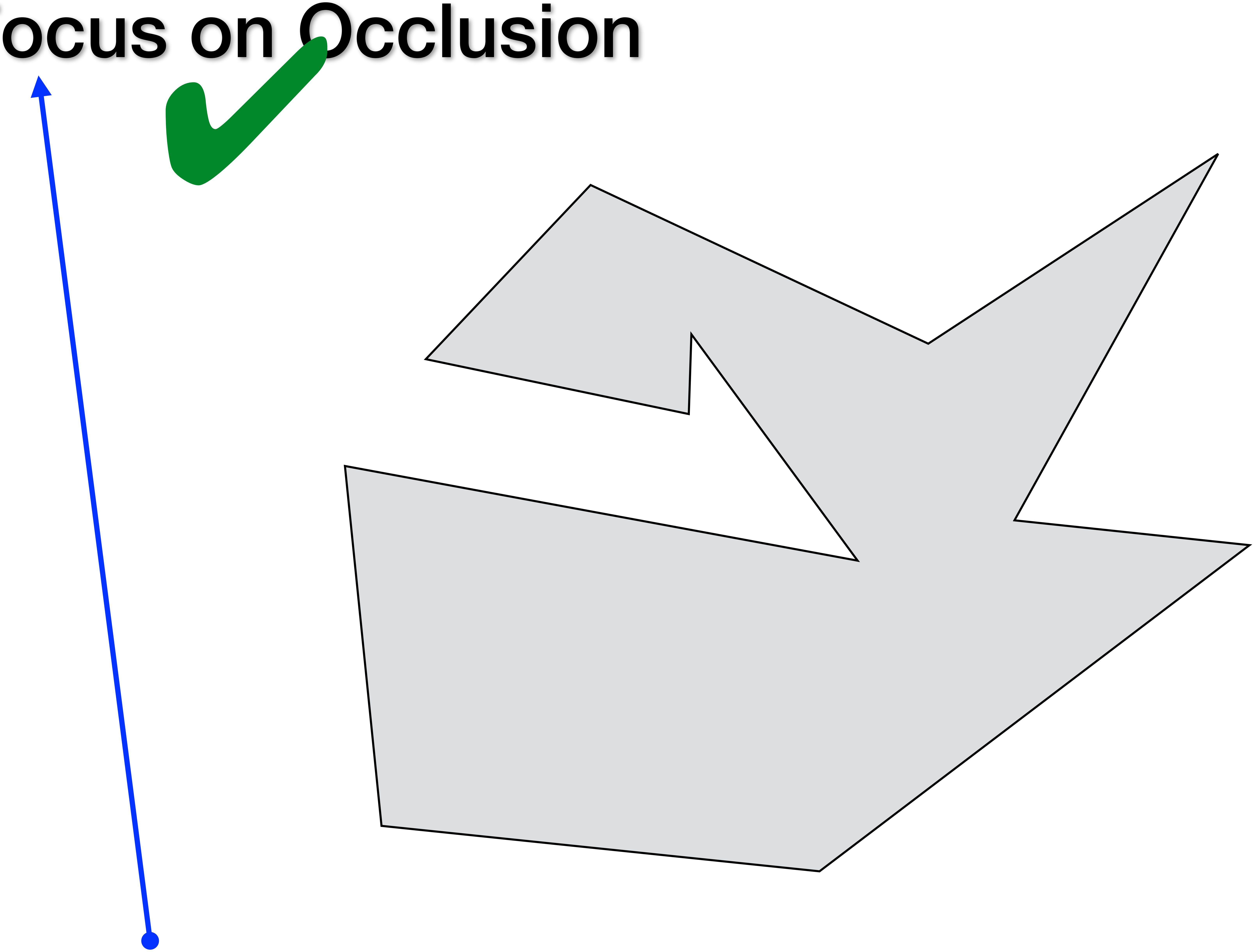

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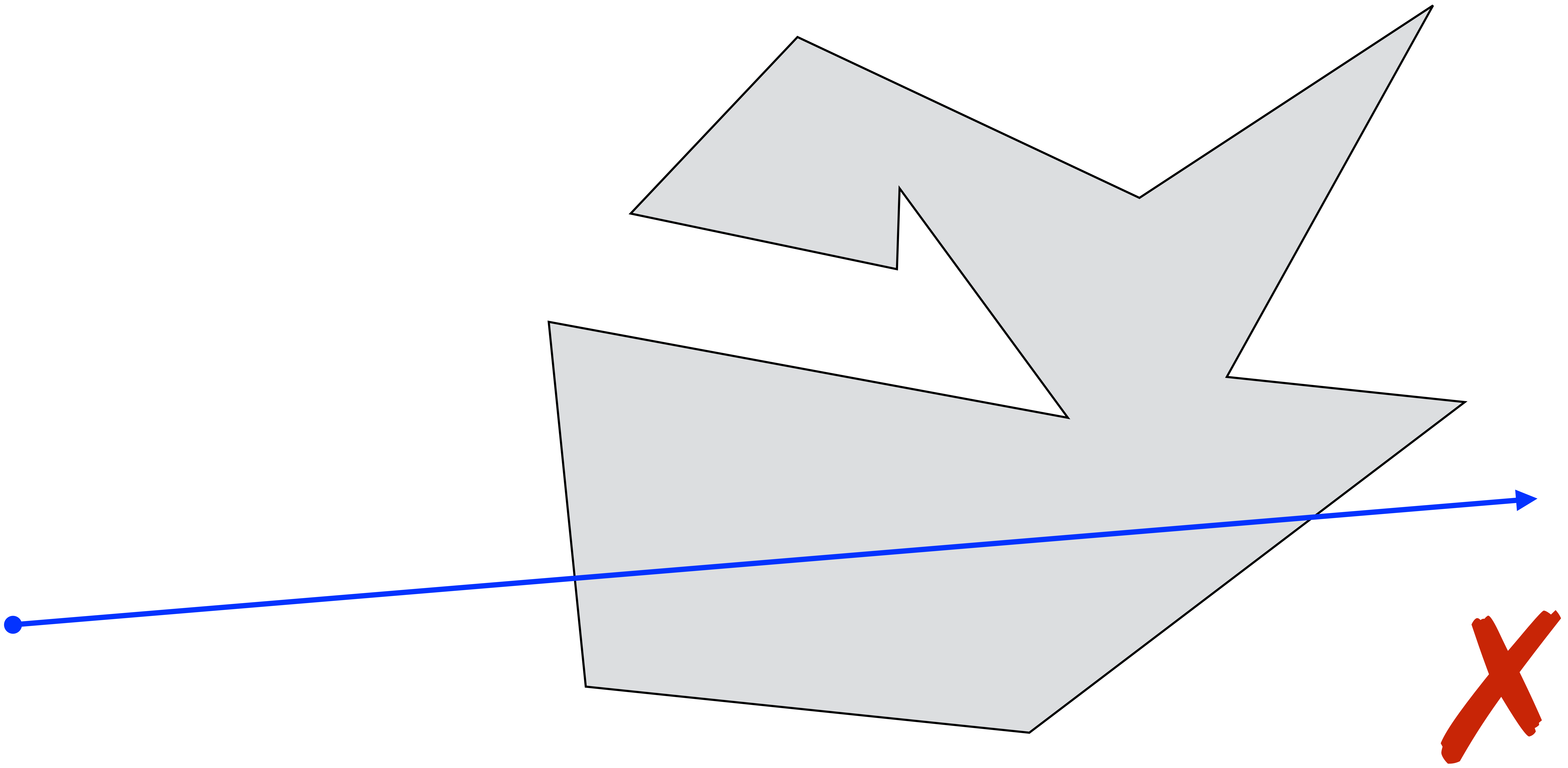
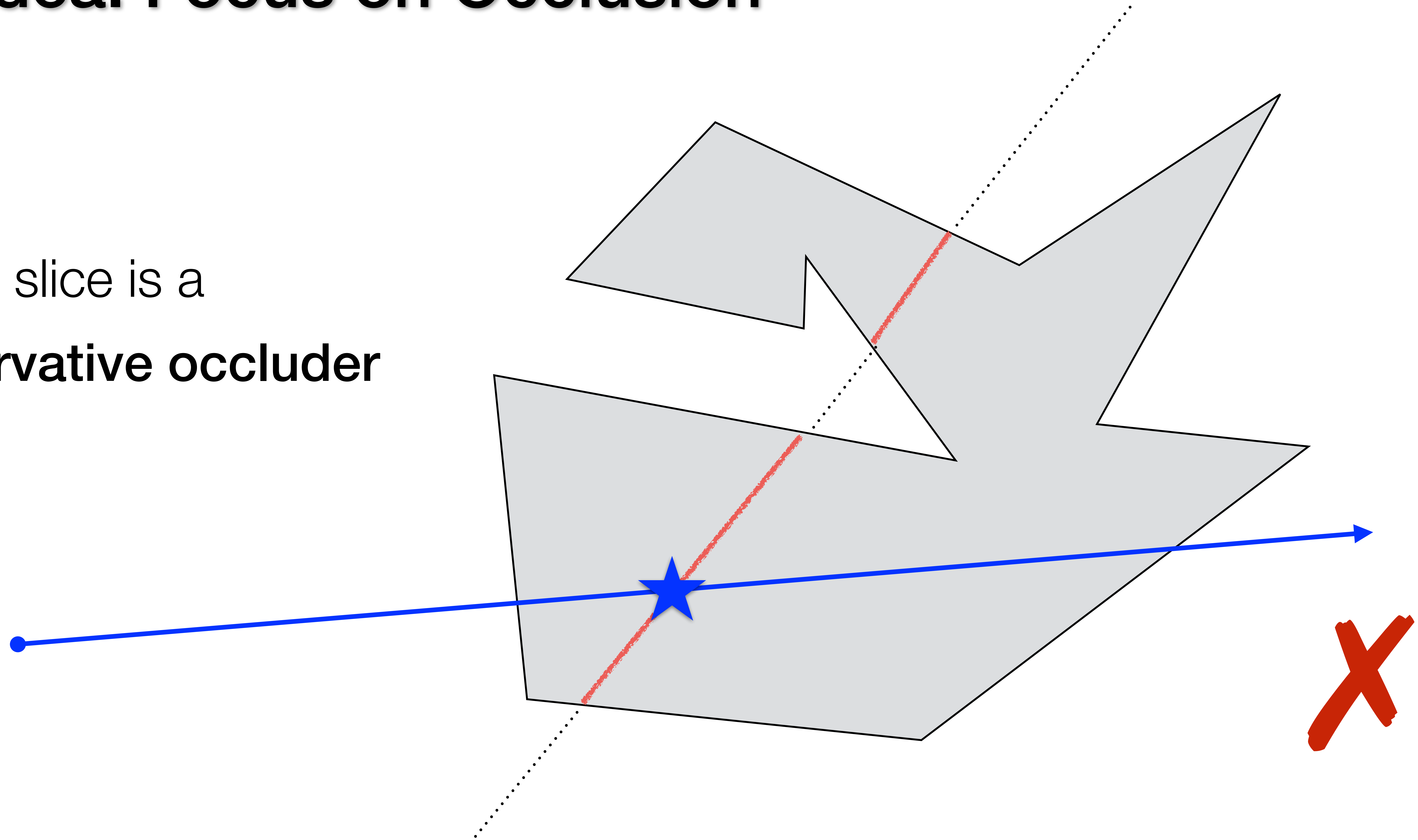


Main Idea: Focus on Occlusion

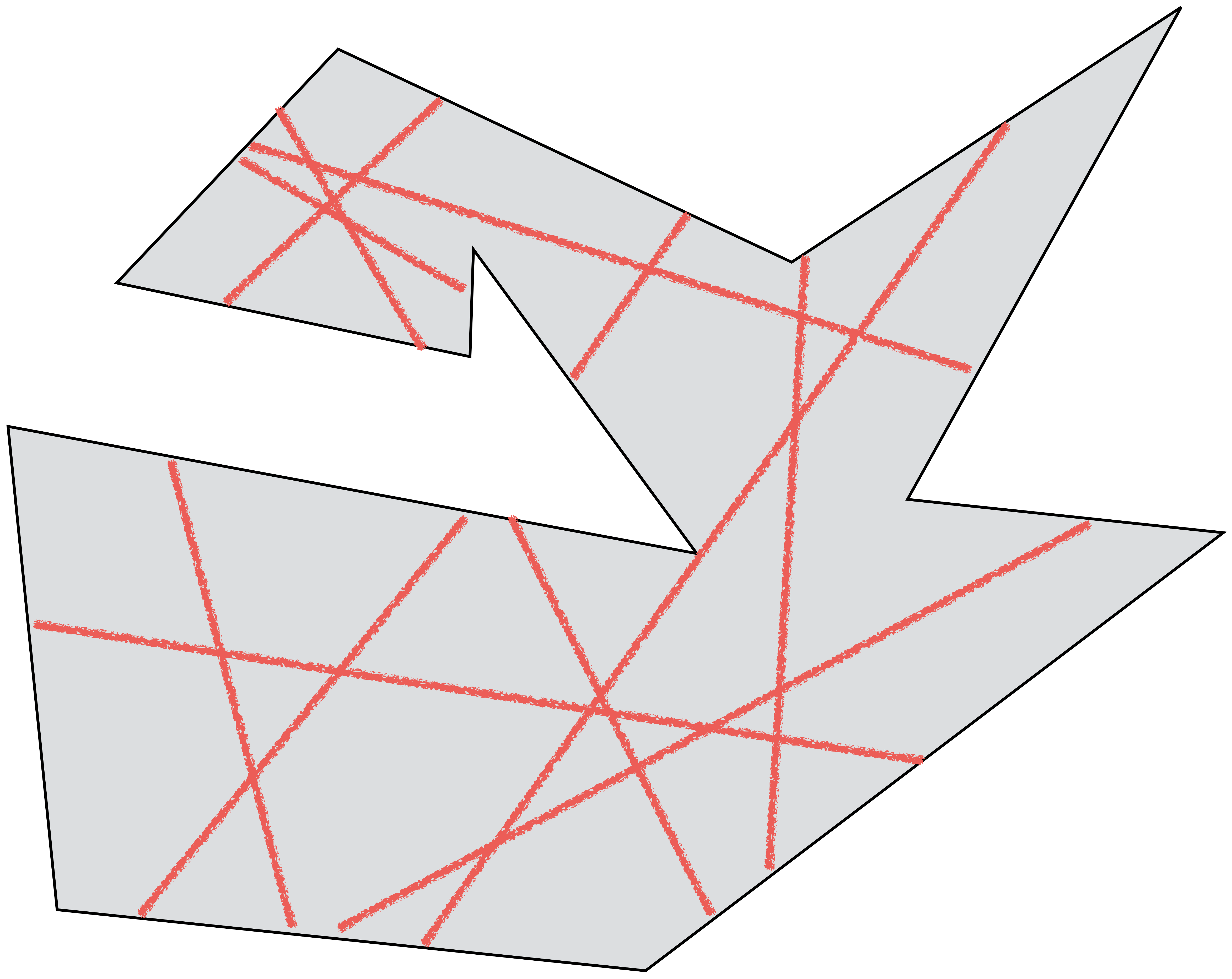
Interior slice is a

conservative occluder



Main Idea: Focus on Occlusion

Line soup and polygon have **similar** occlusion characteristics



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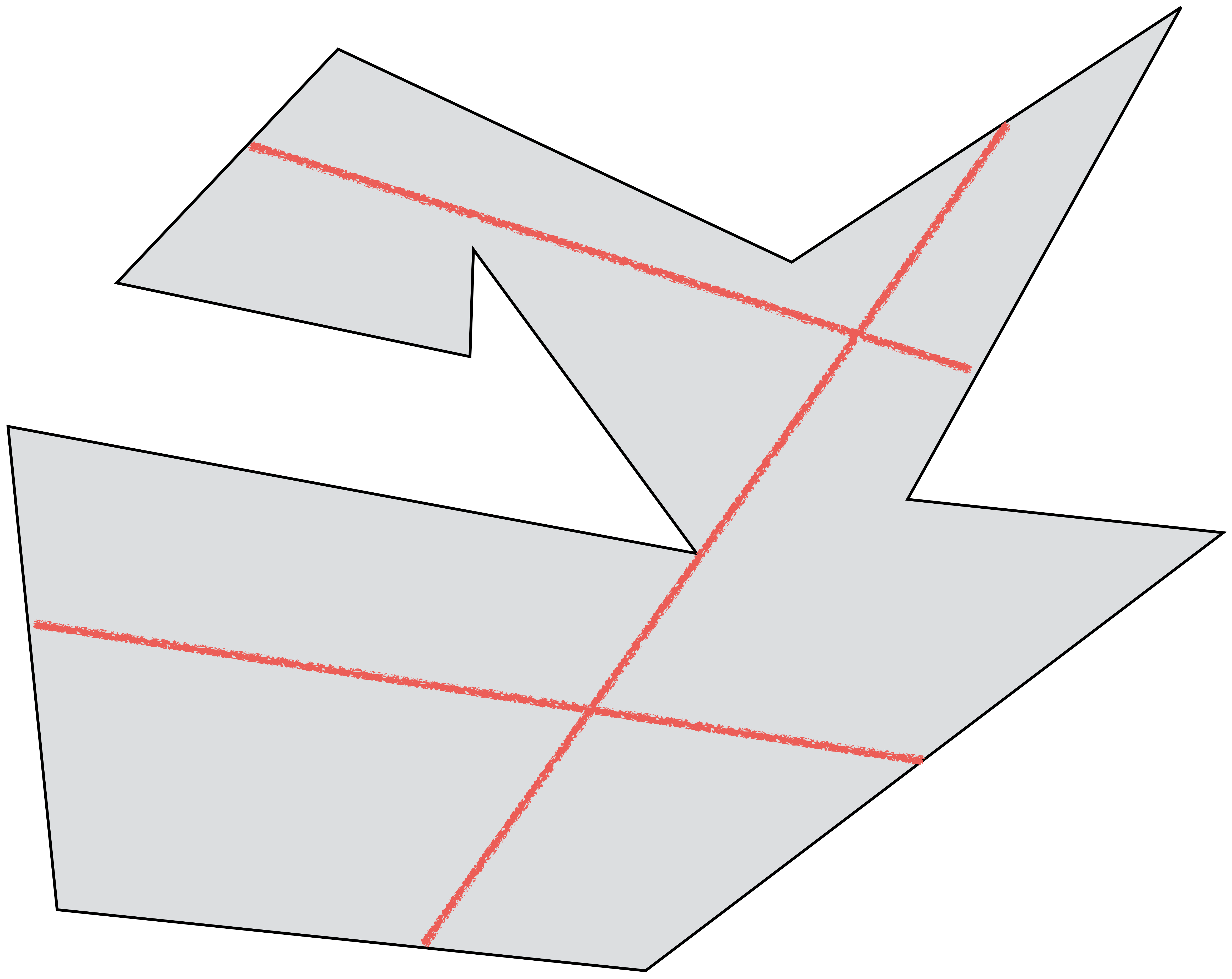
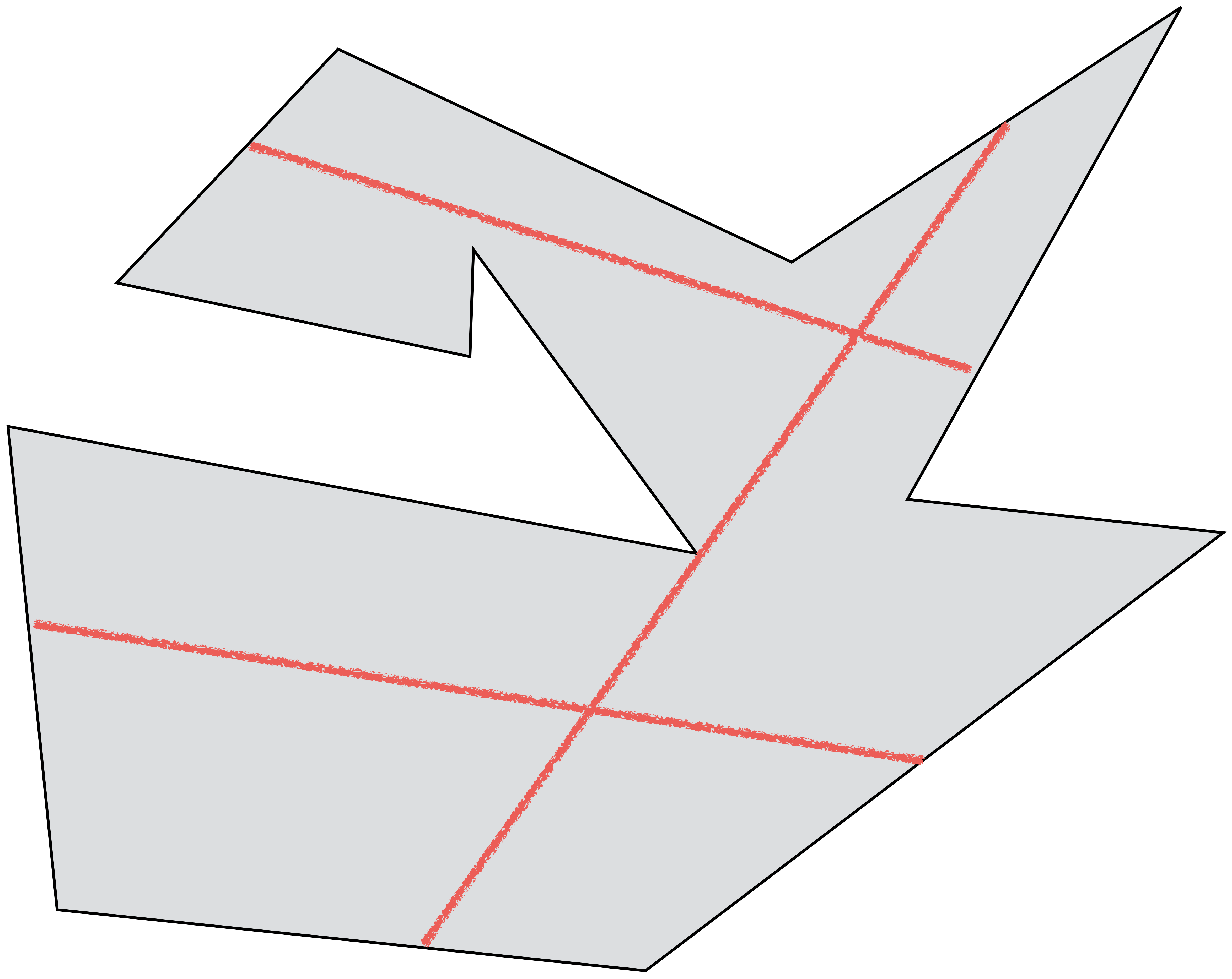


Main Idea: Focus on Occlusion

Focusing on occlusion gives us **more freedom**

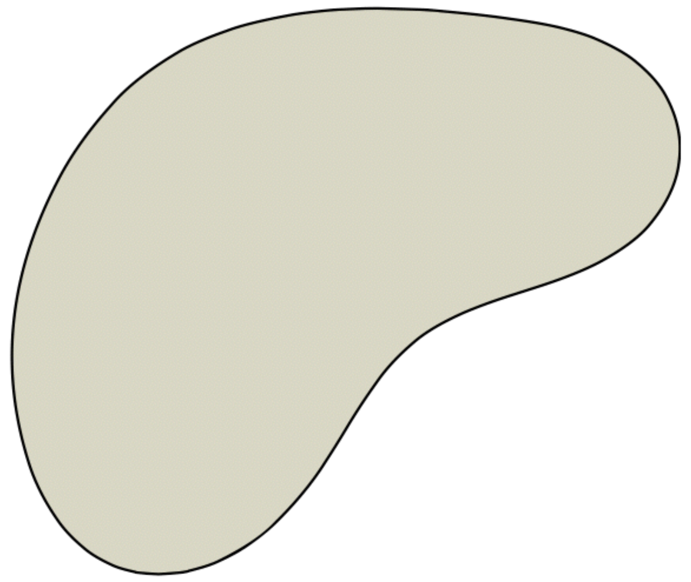


Algorith Sketch

1. Cut the model using a large number of planes
2. Assemble the cuts such they satisfy our budget and **maximise occlusion similarity**

How to Quantify Occlusion?

Surface Area?



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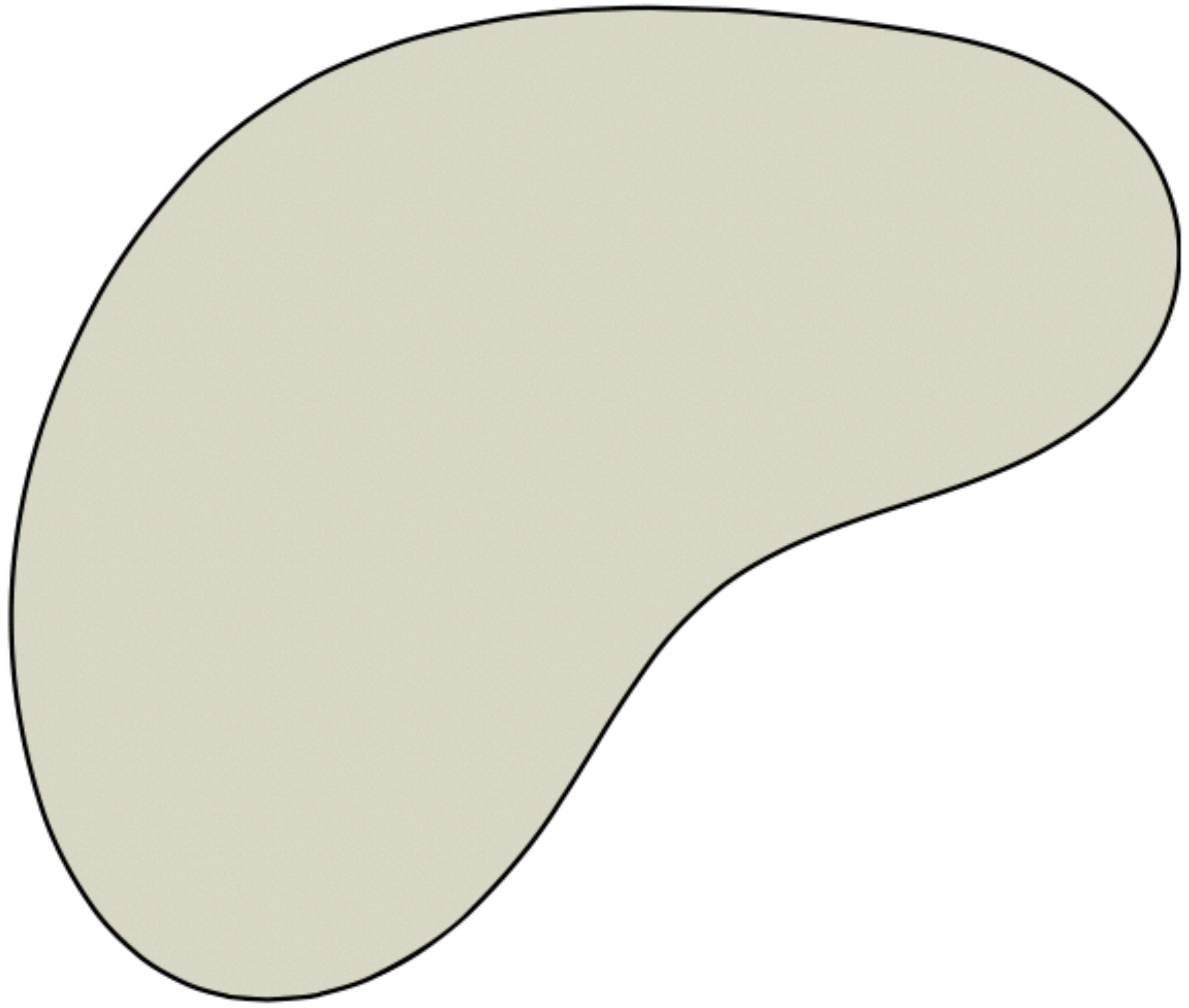
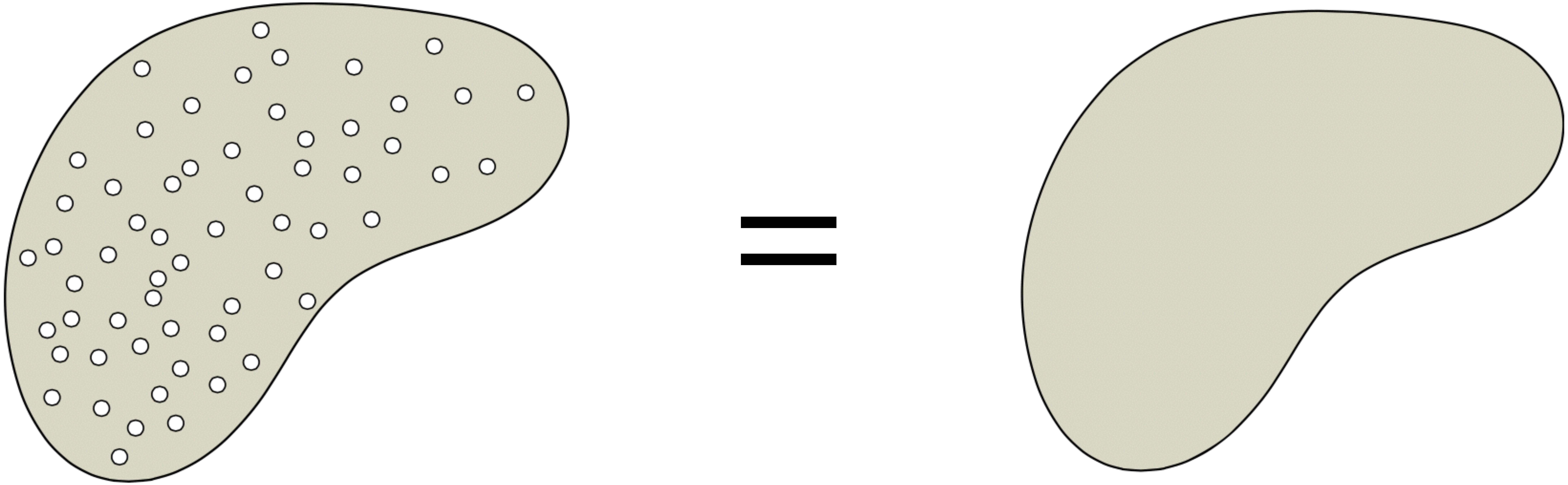
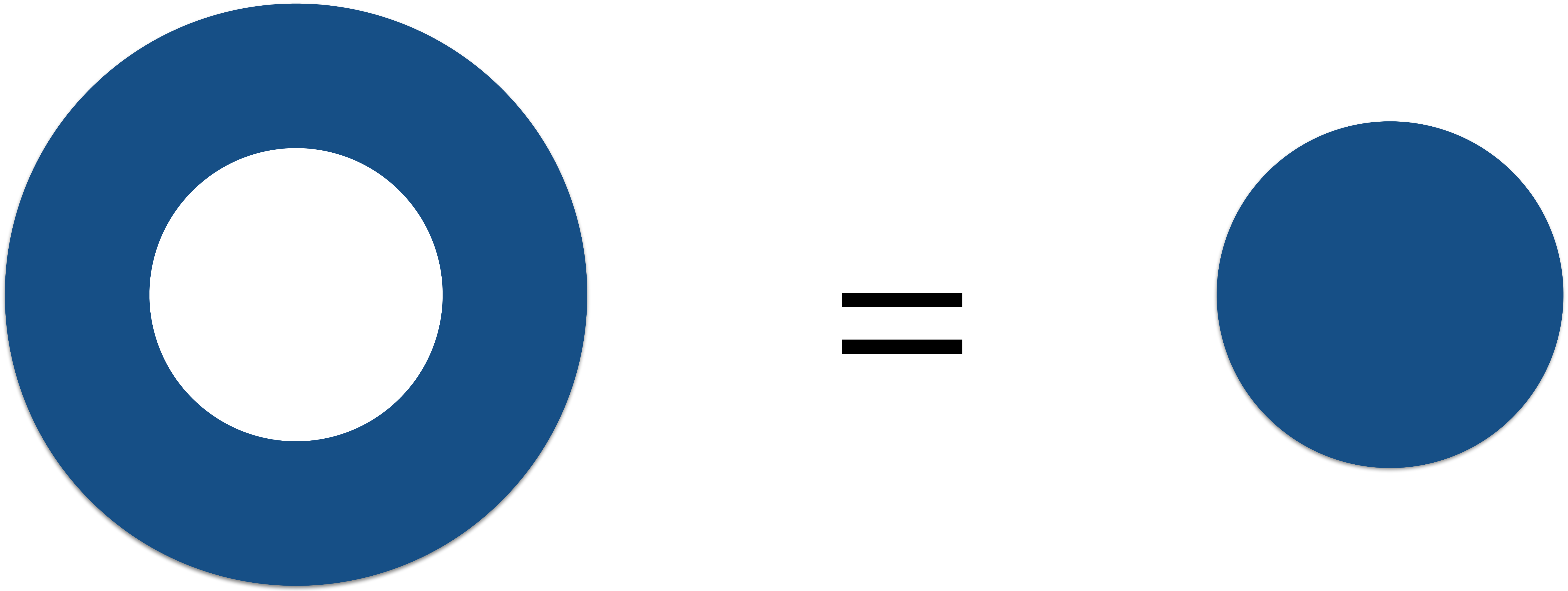


Surface Area?



Topological Erosion

Why is a sphere a **better occluder** than a torus?



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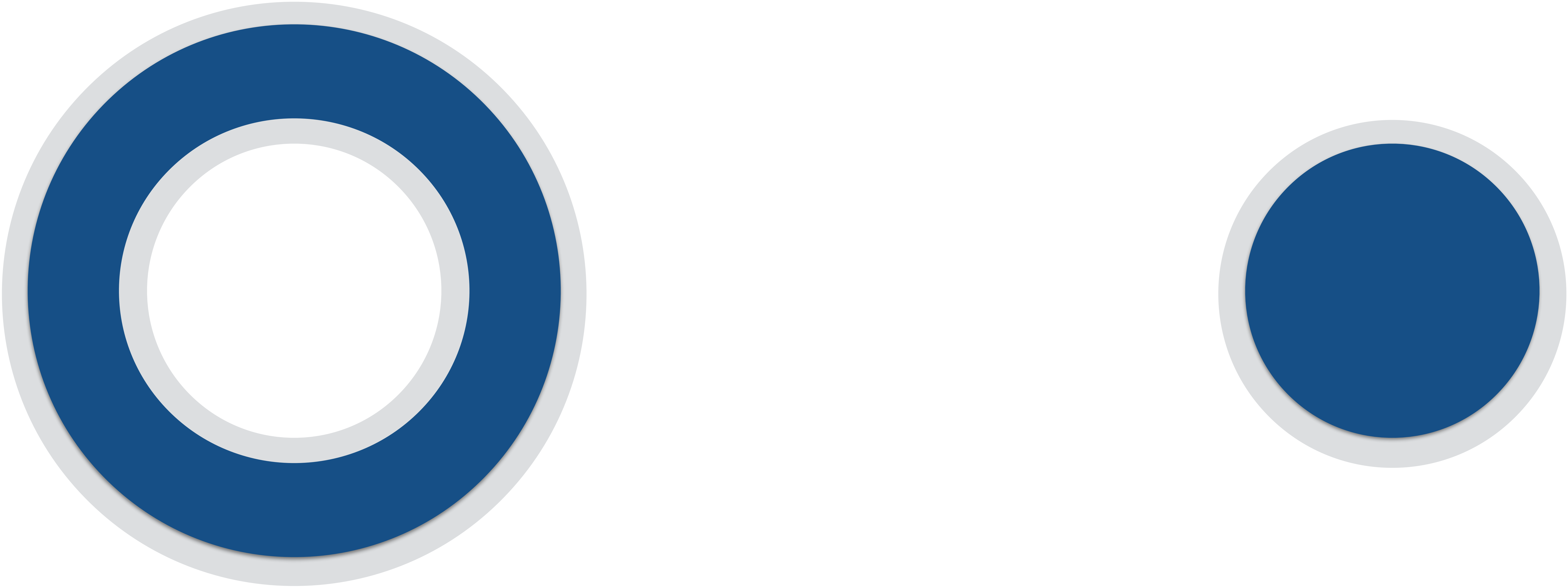

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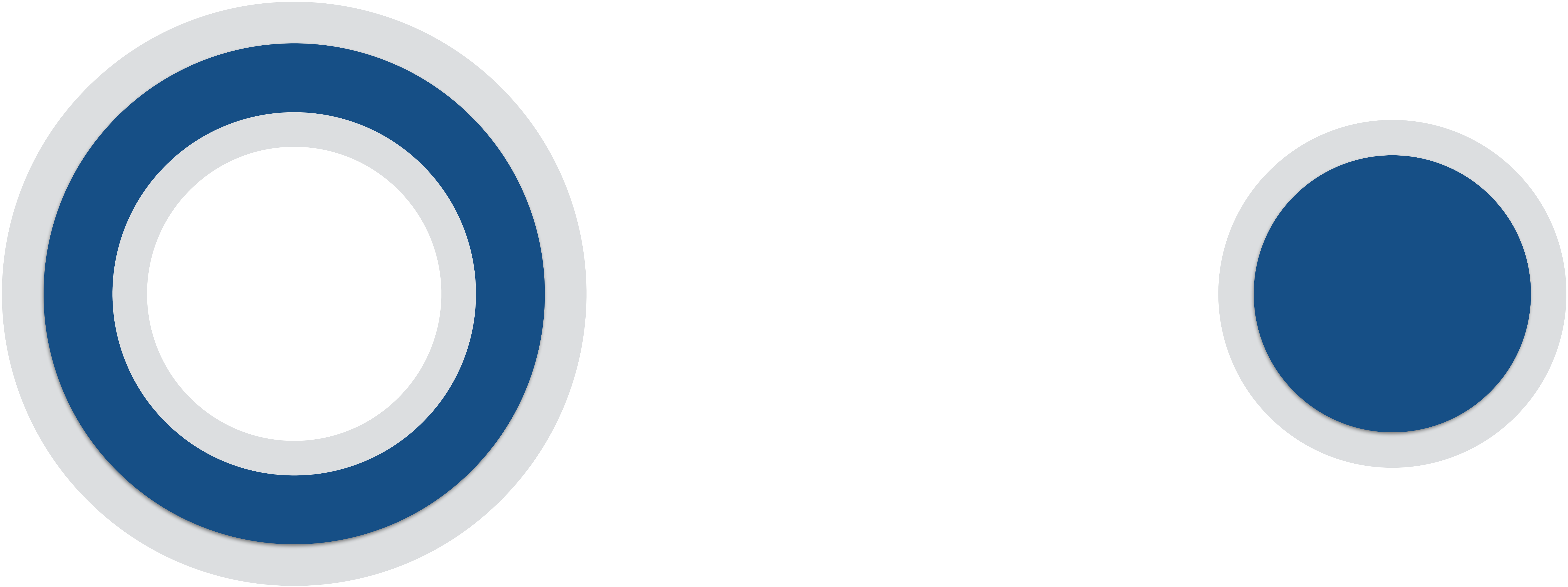

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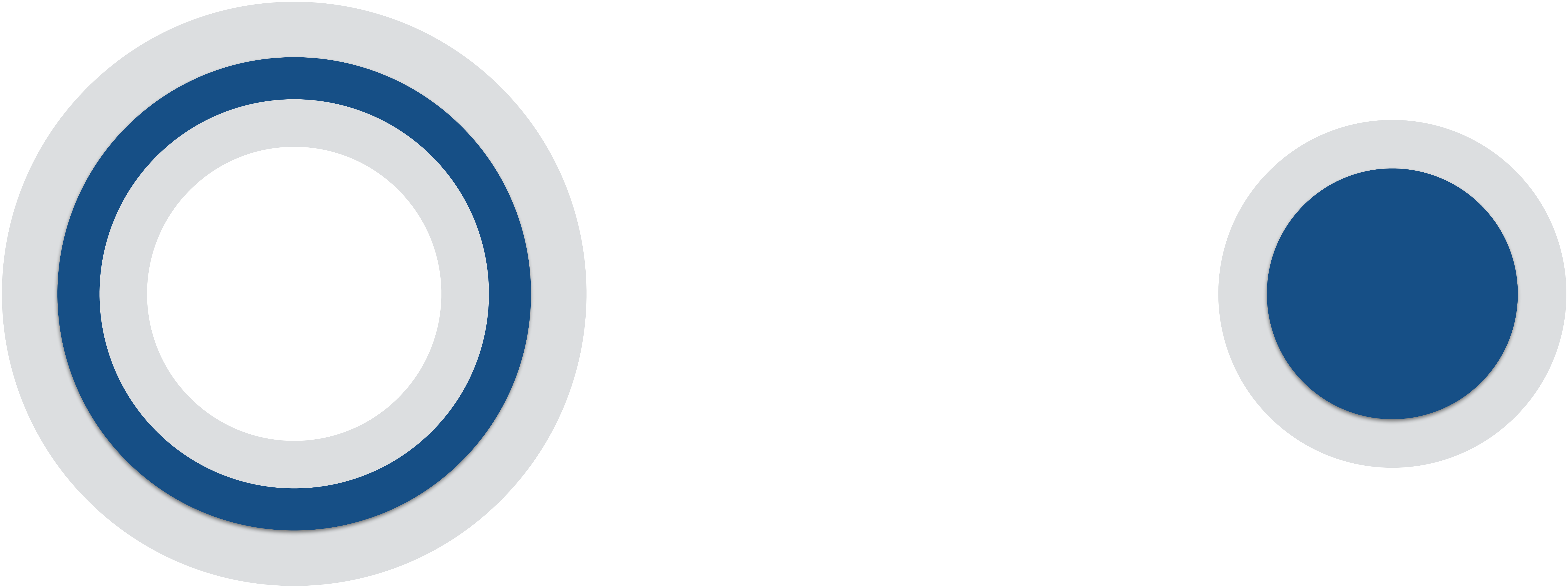

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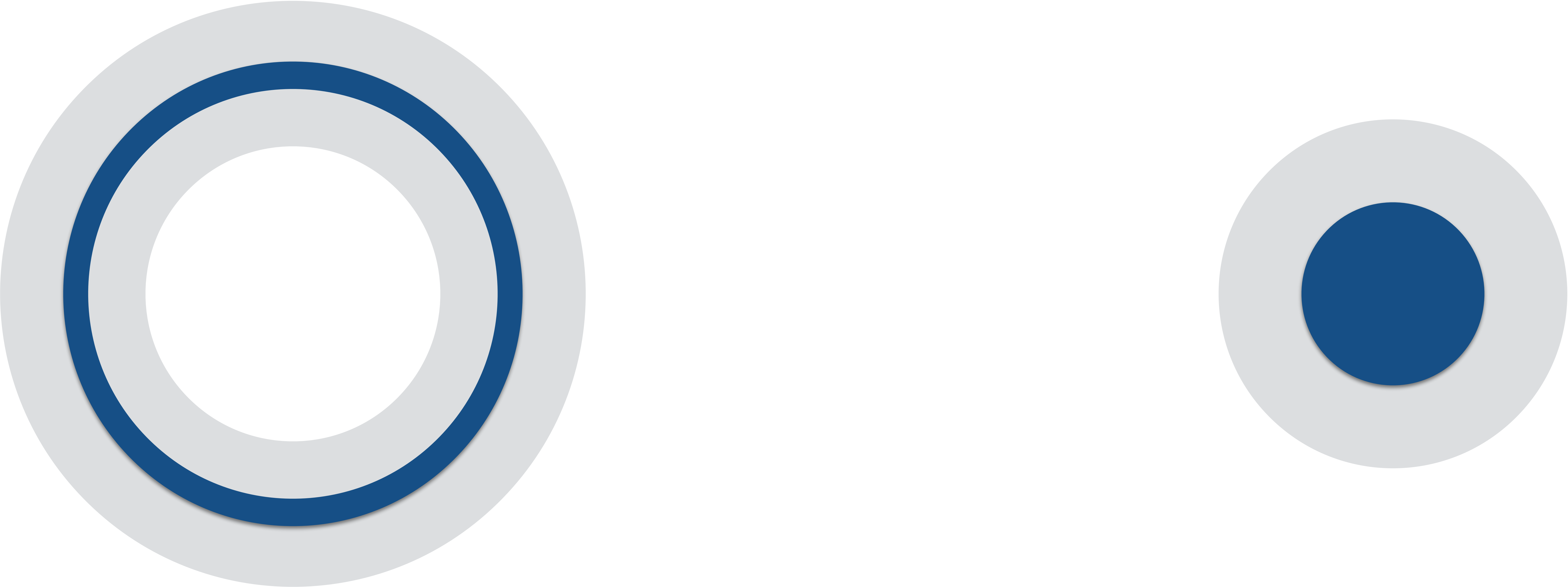

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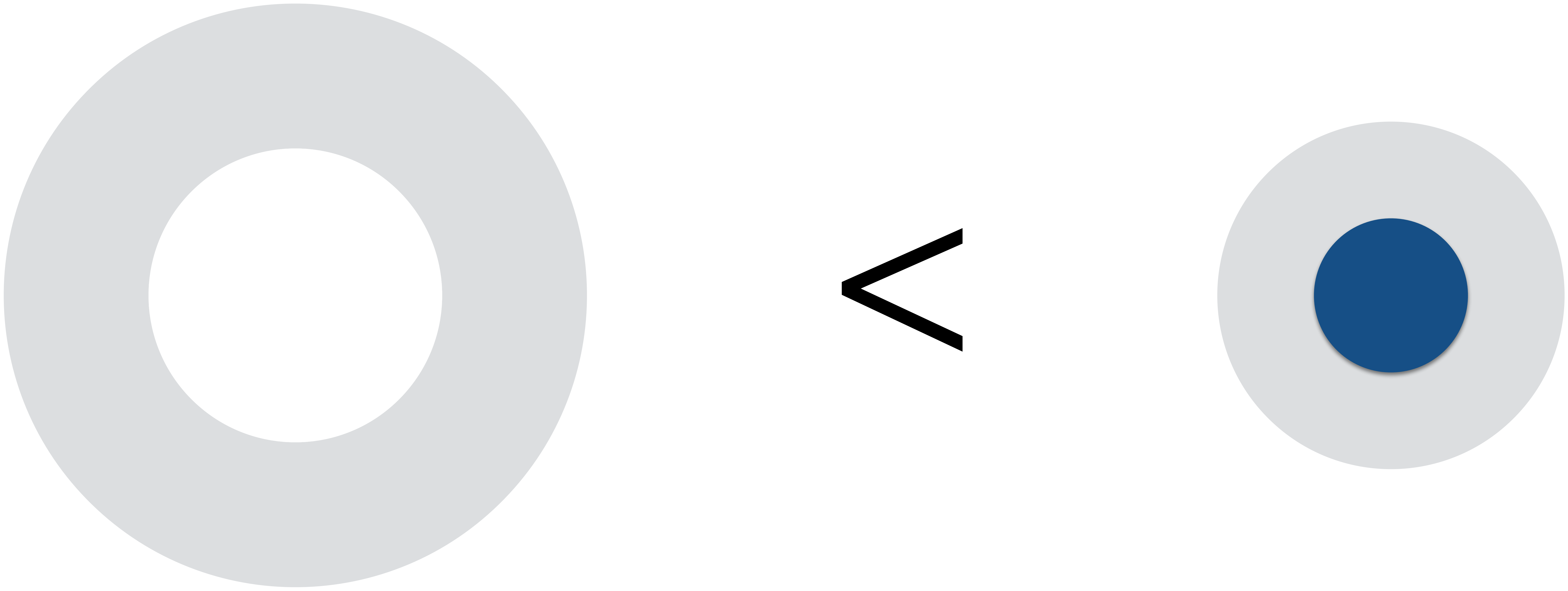

Measuring Occlusion

Surface area **after** erosion

Measuring Occlusion

$$\int_{\Omega}\int_{0}^{\infty} \text{Surface area } \textbf{after} \text{ erosion } \,\mathrm{d}r\,\mathrm{d}\omega$$

Algorithm Outline

1. **Voxelize** the input model and build a closed model with a well defined interior
2. **Generate** a large number of planar polygons by sampling the interior of the voxel model
3. **Assemble** the polygons such that they satisfy our budget and maximise total occlusion measure

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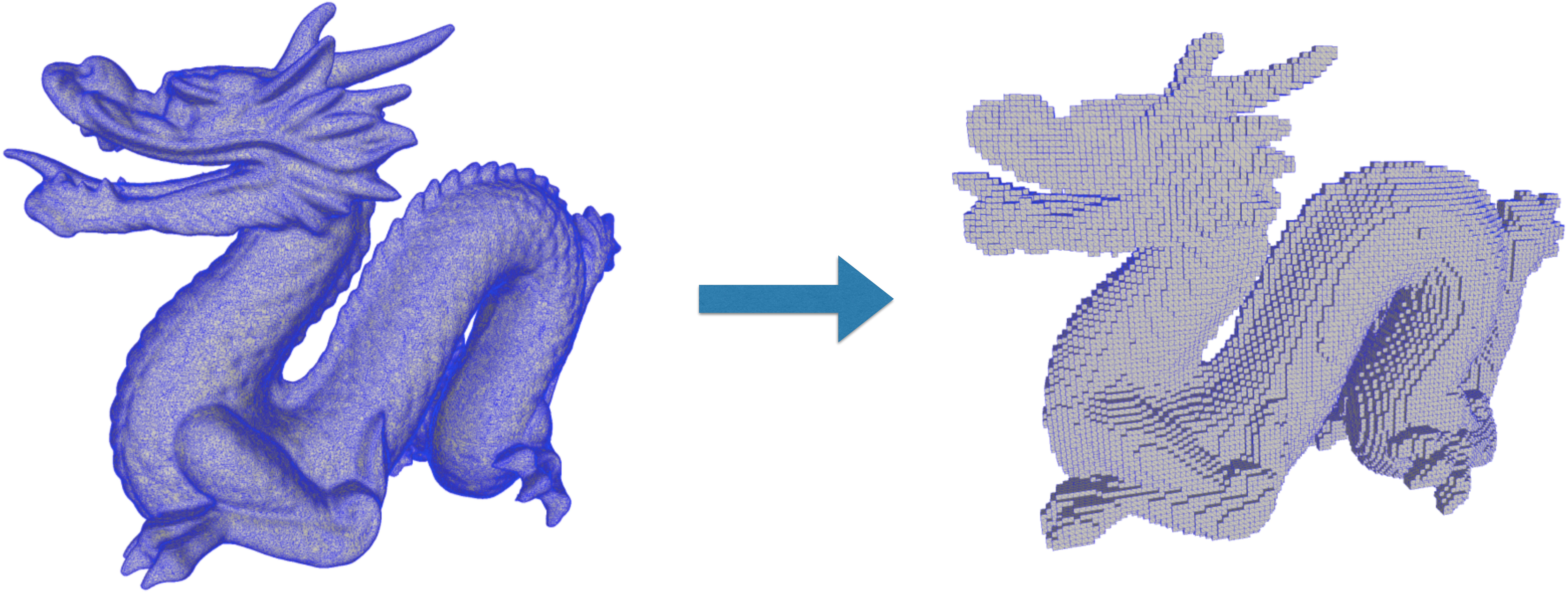
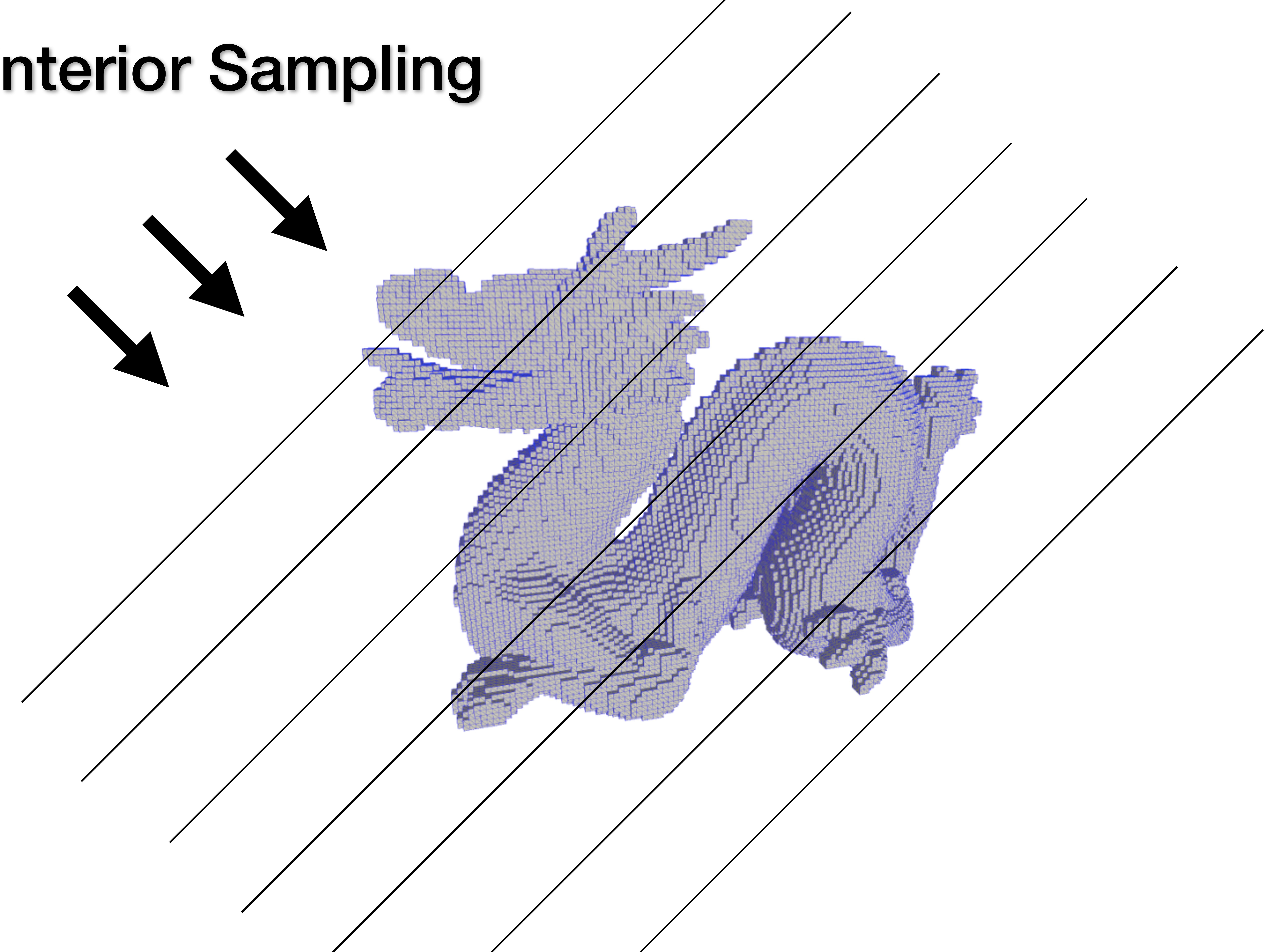
1. Voxelization



2. Interior Sampling



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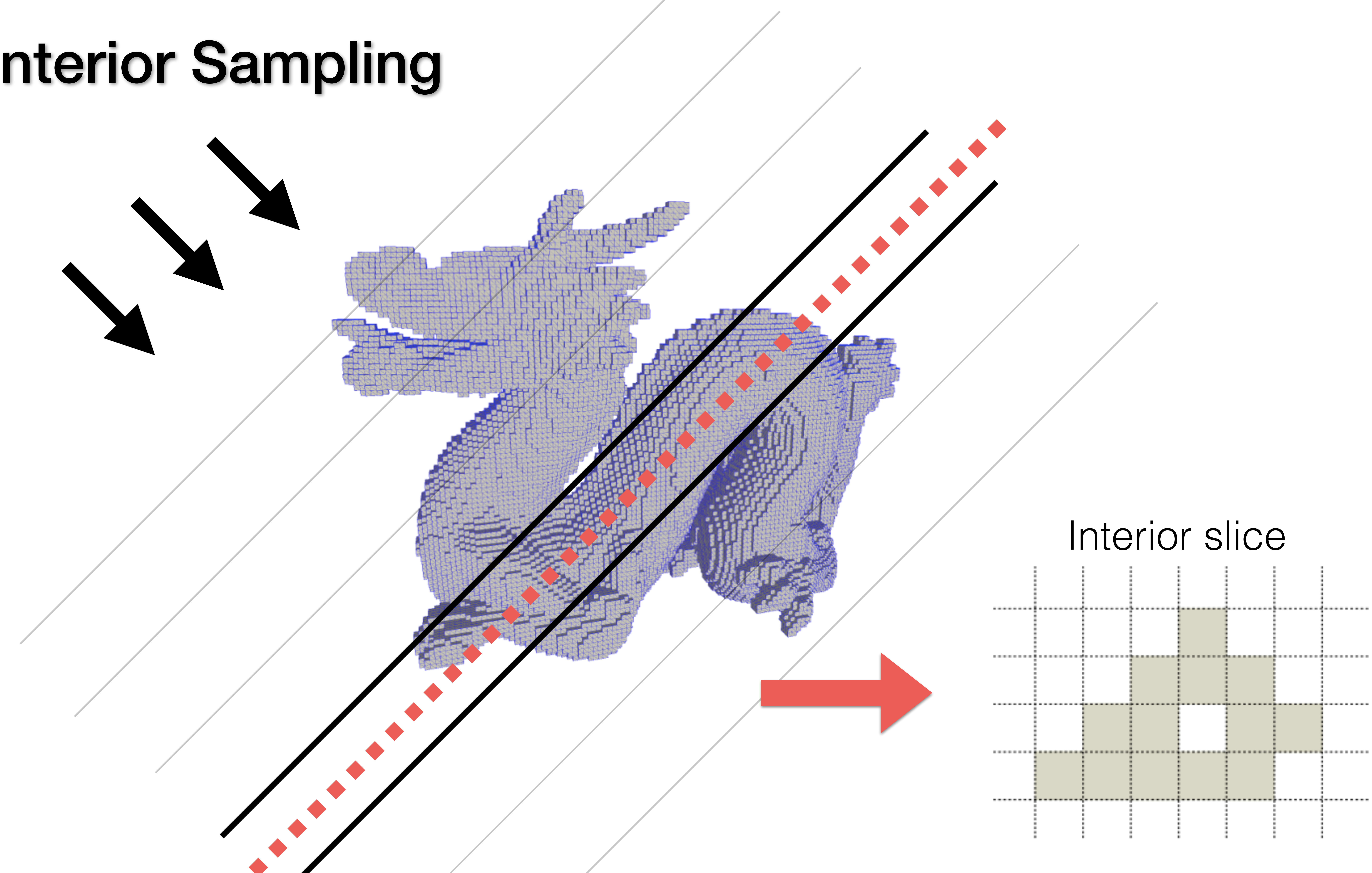
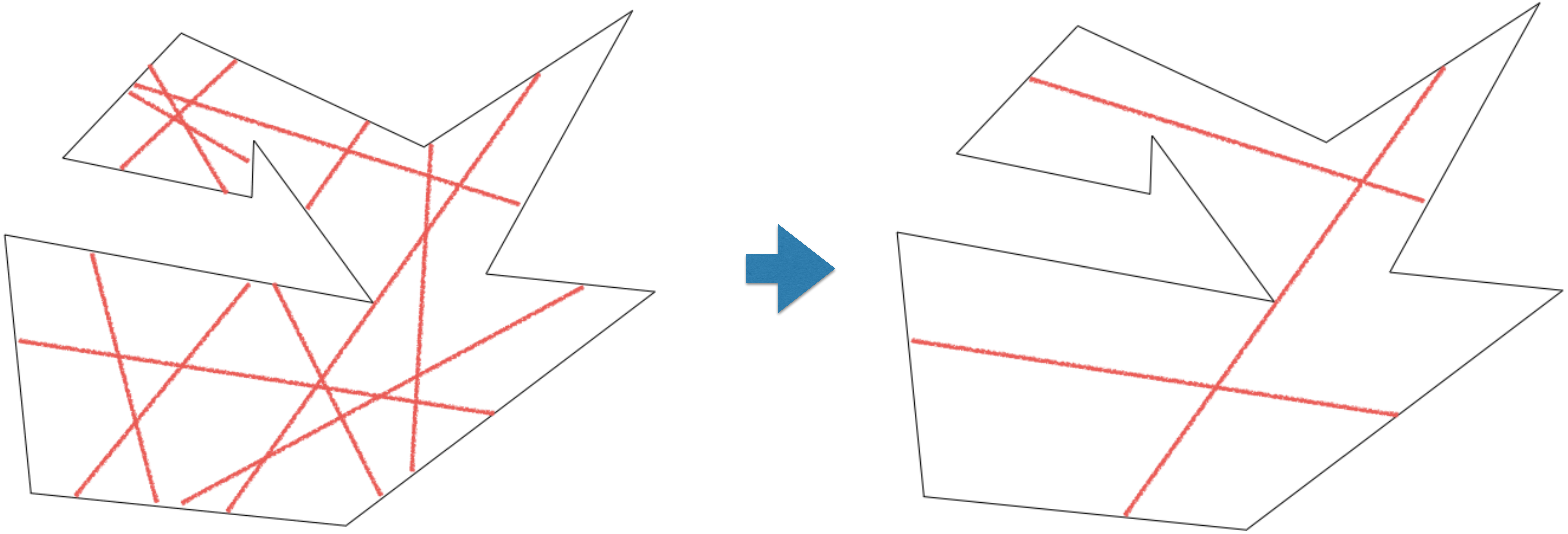


2. Interior Sampling

Rasterized interior slice

Polygons

3. Occluder Assembly



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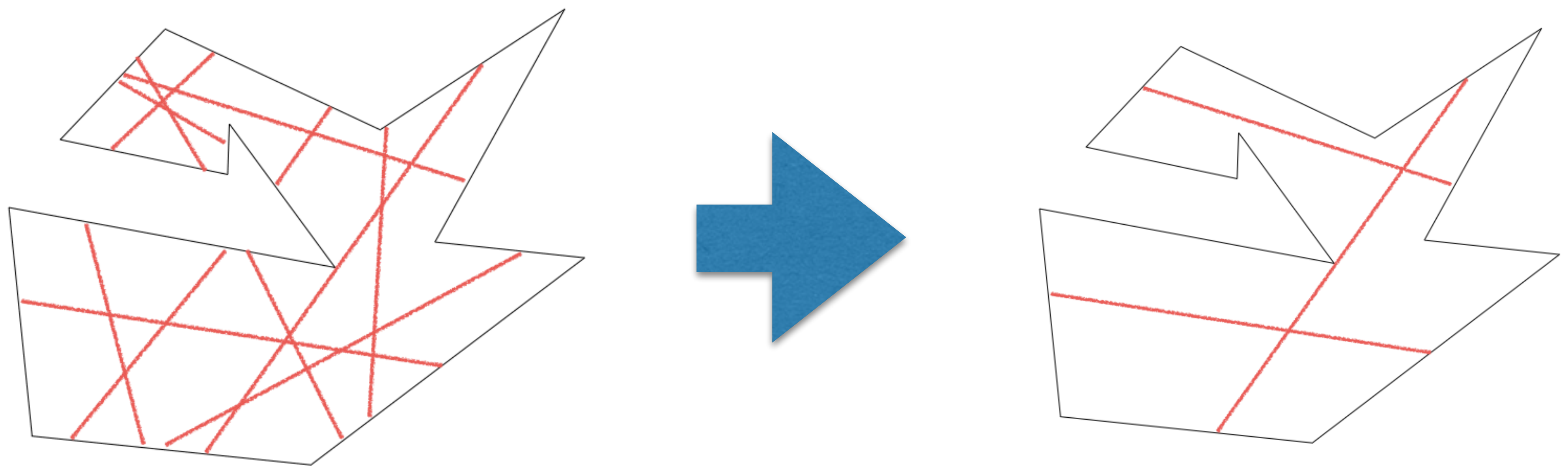
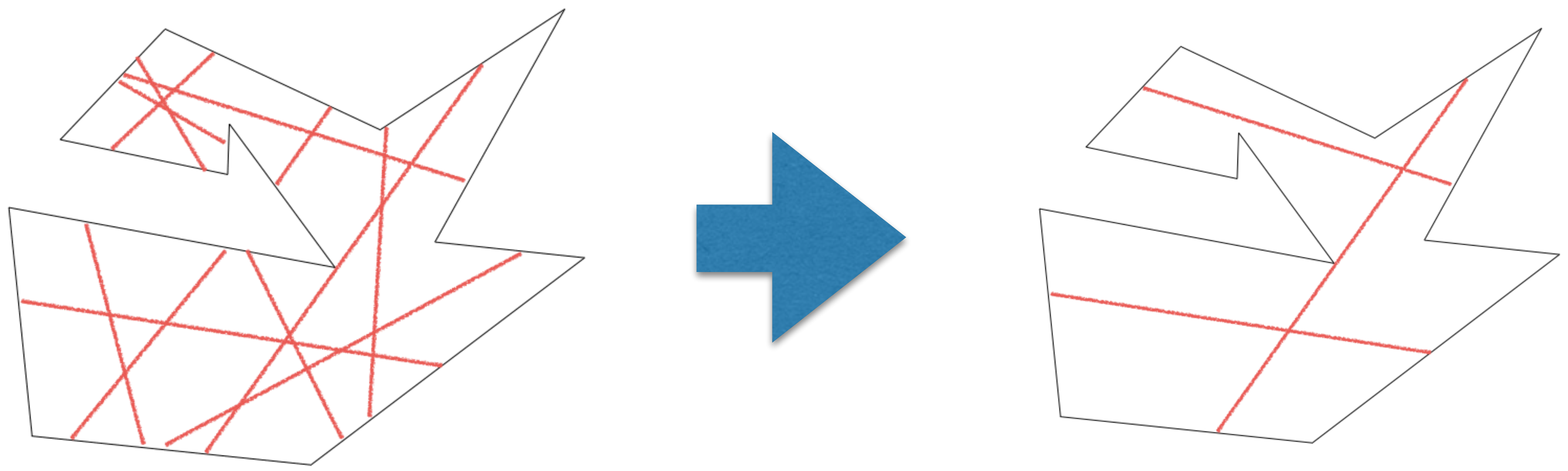


Use a **greedy** method to pick one polygon at a time

Evaluate **total occlusion measure** for each possible choice and choose the **maximal** one

Iterate the process until the occluder is complete

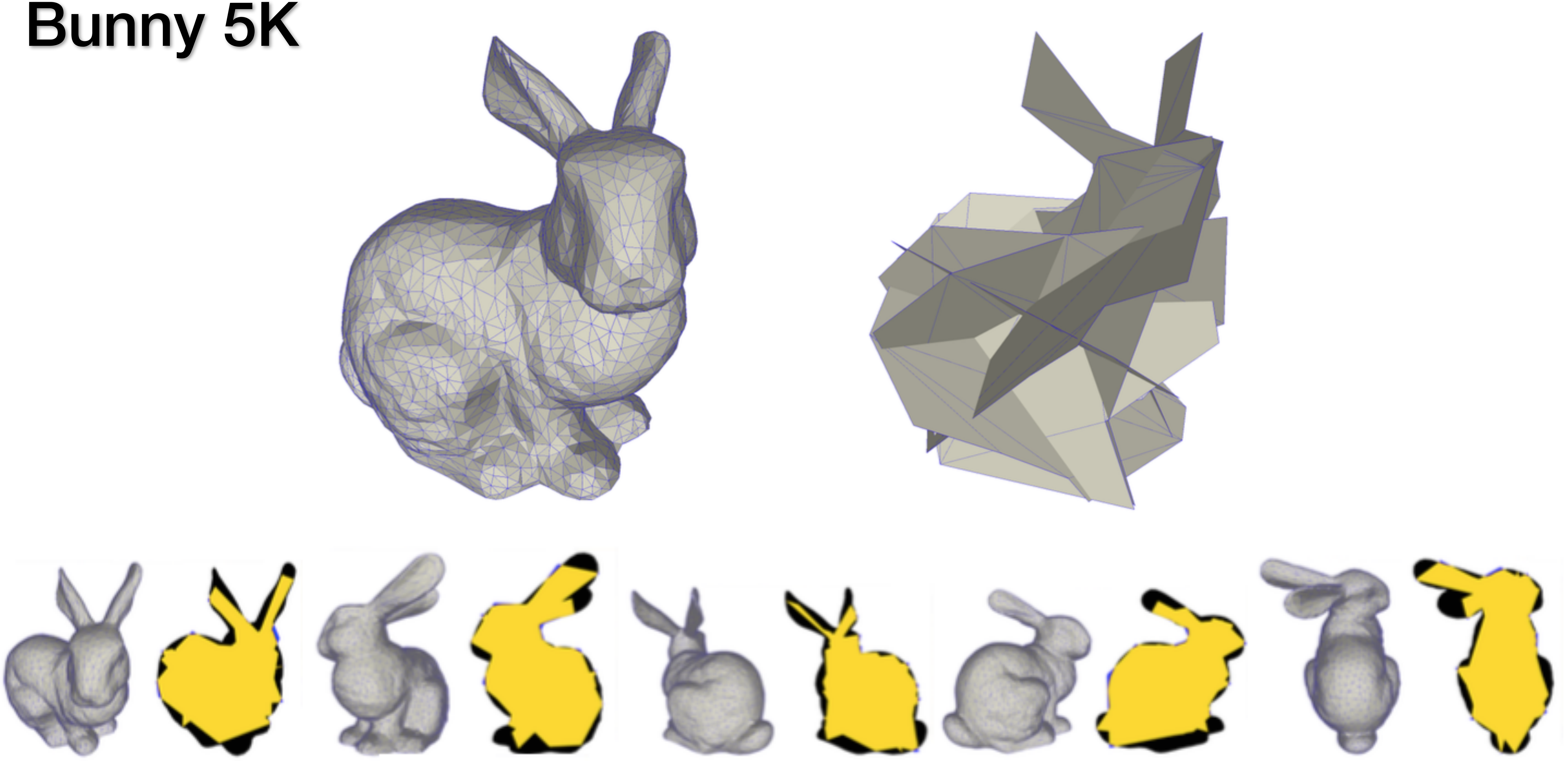
3. Occluder Assembly



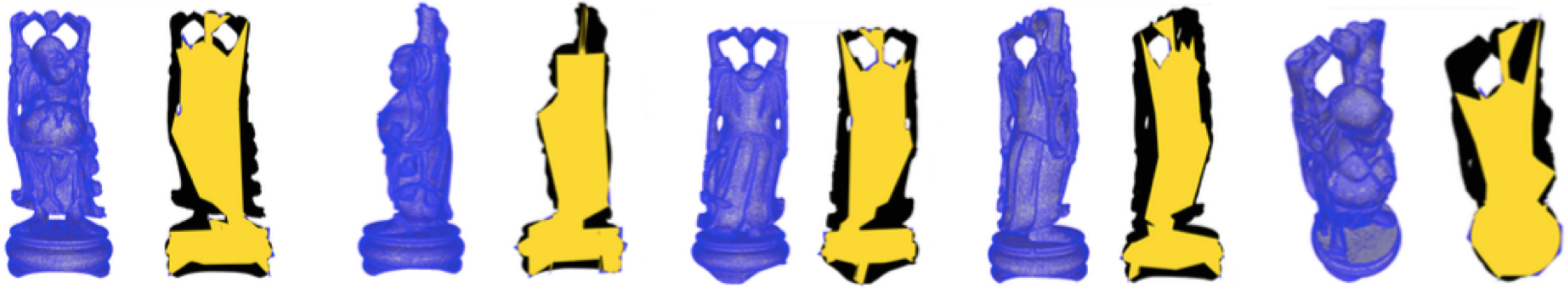
The resulting occluder might still exceed our triangle budget

Remove triangles one-by-one until we reach our budget

Bunny 5K



Buddha



Input 1087474 tris

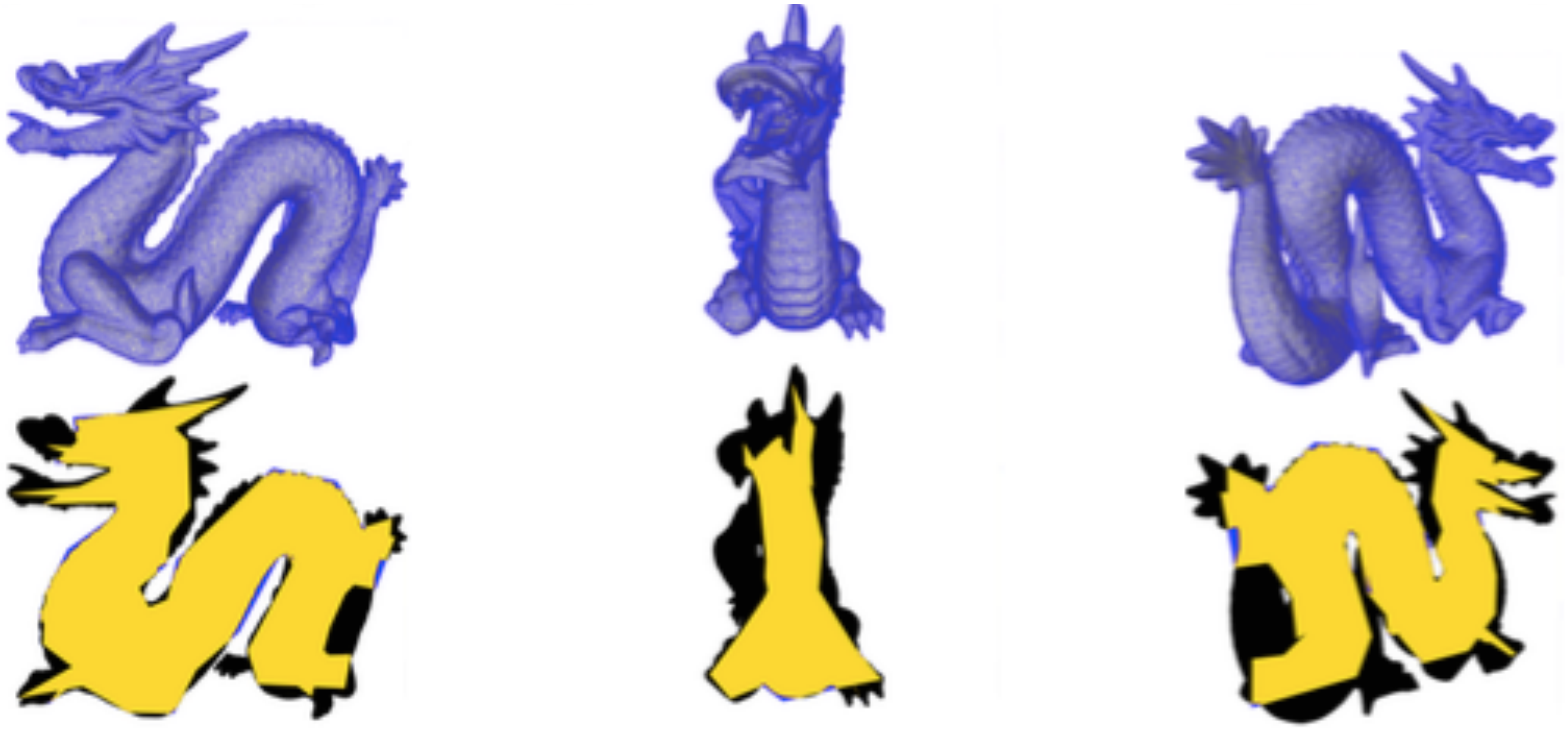
Output 64 tris

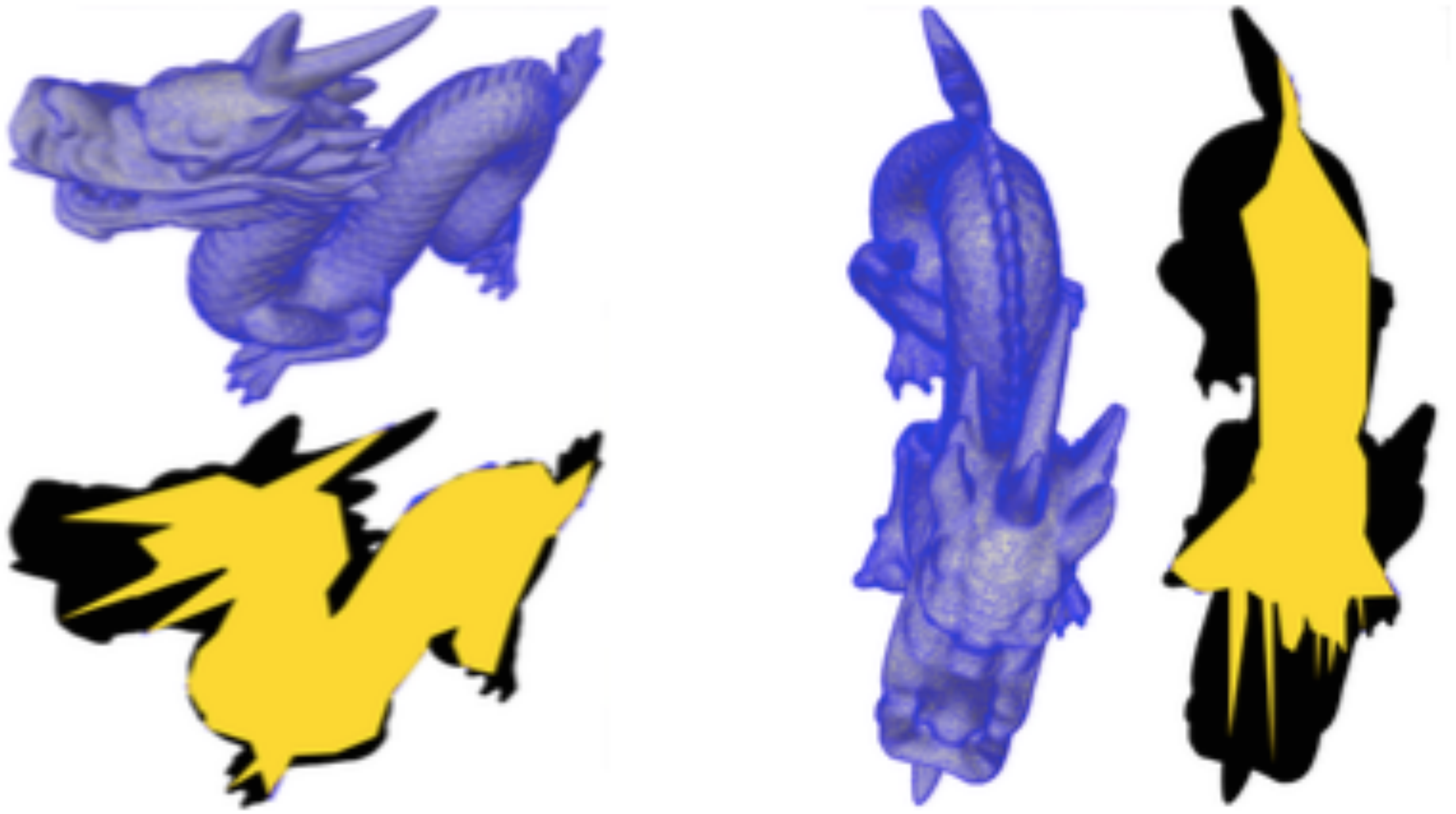
Machine

Input 394452 tris

Output 64 tris

Dragon

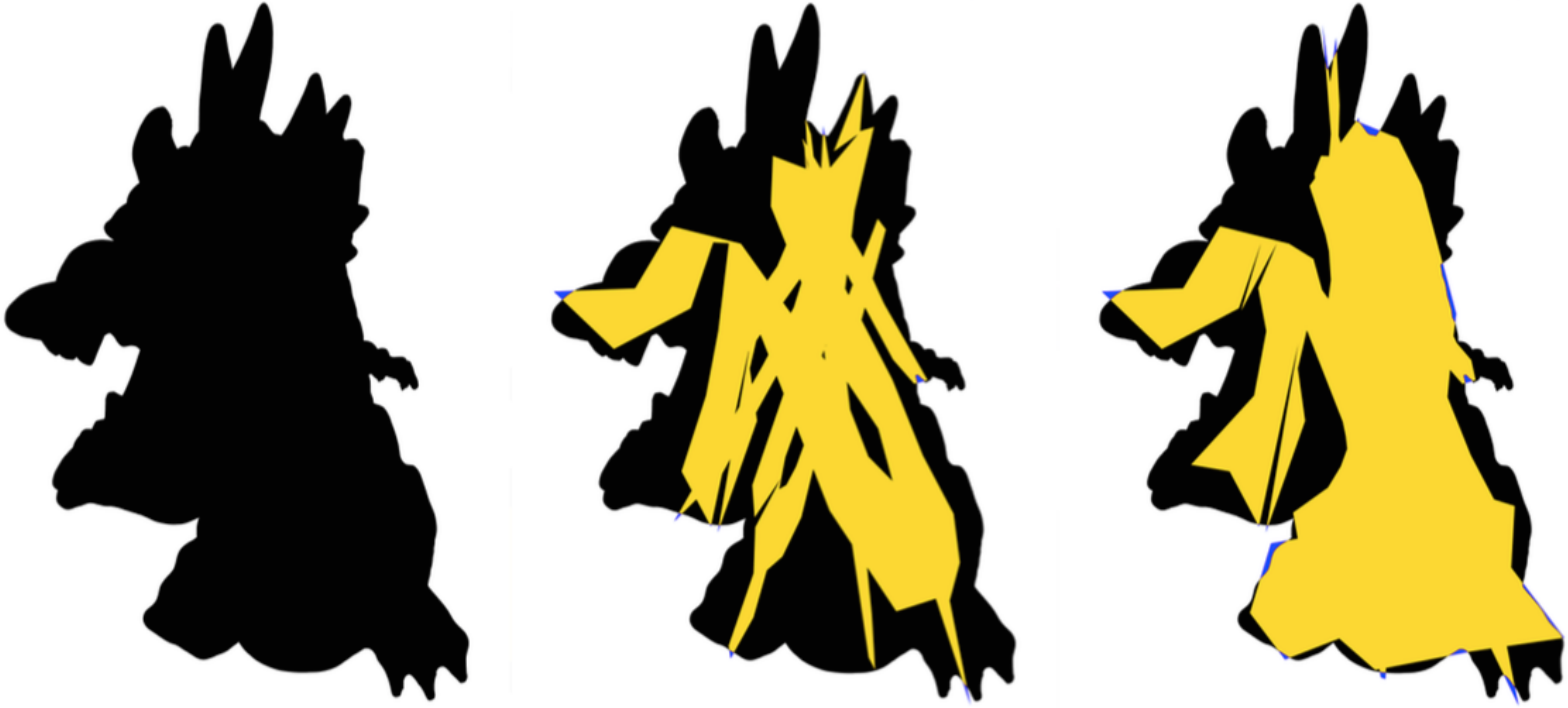




Input 871306 tris

Output 64 tris

Surface Area vs. Occlusion Measure

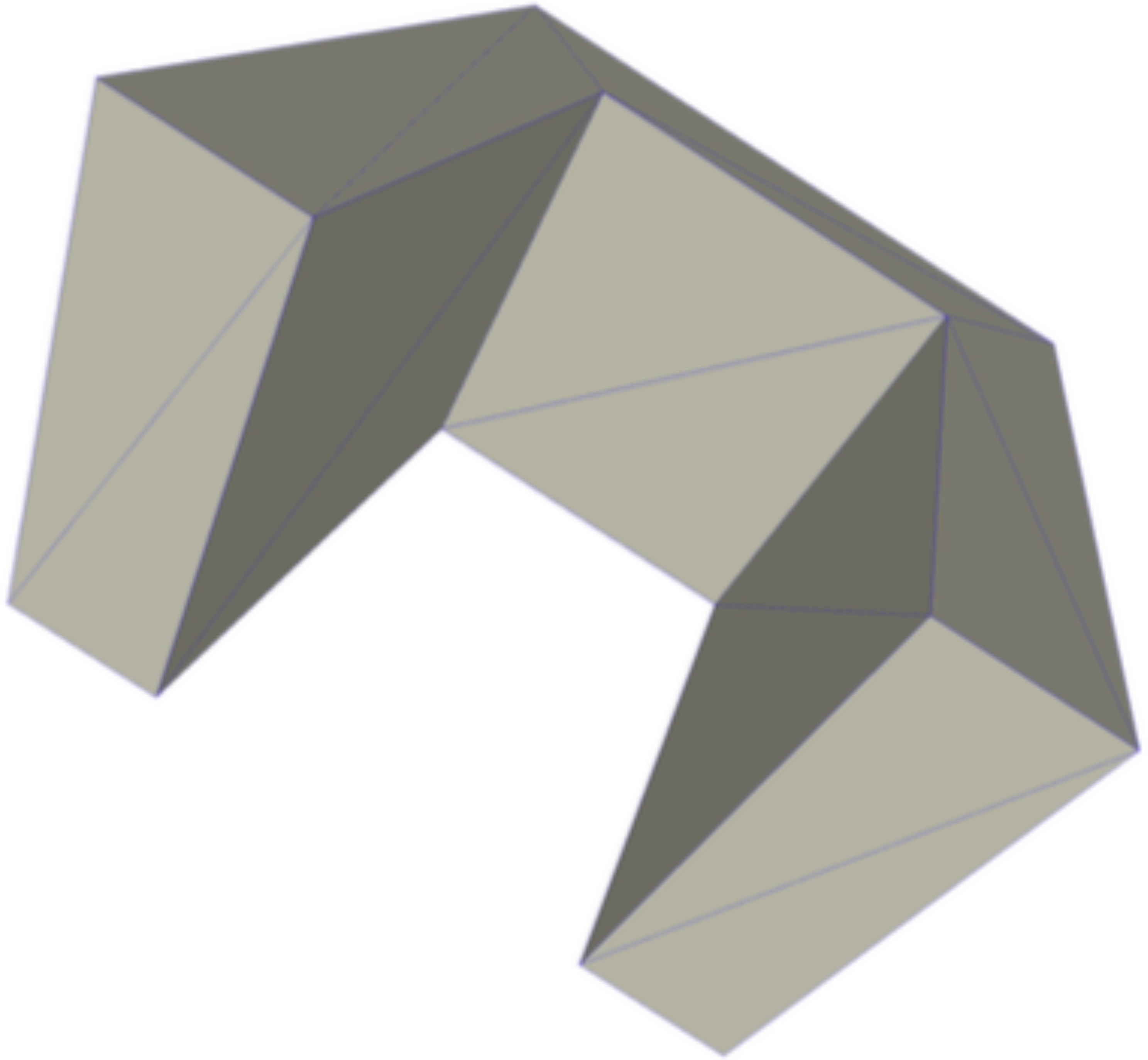


Input

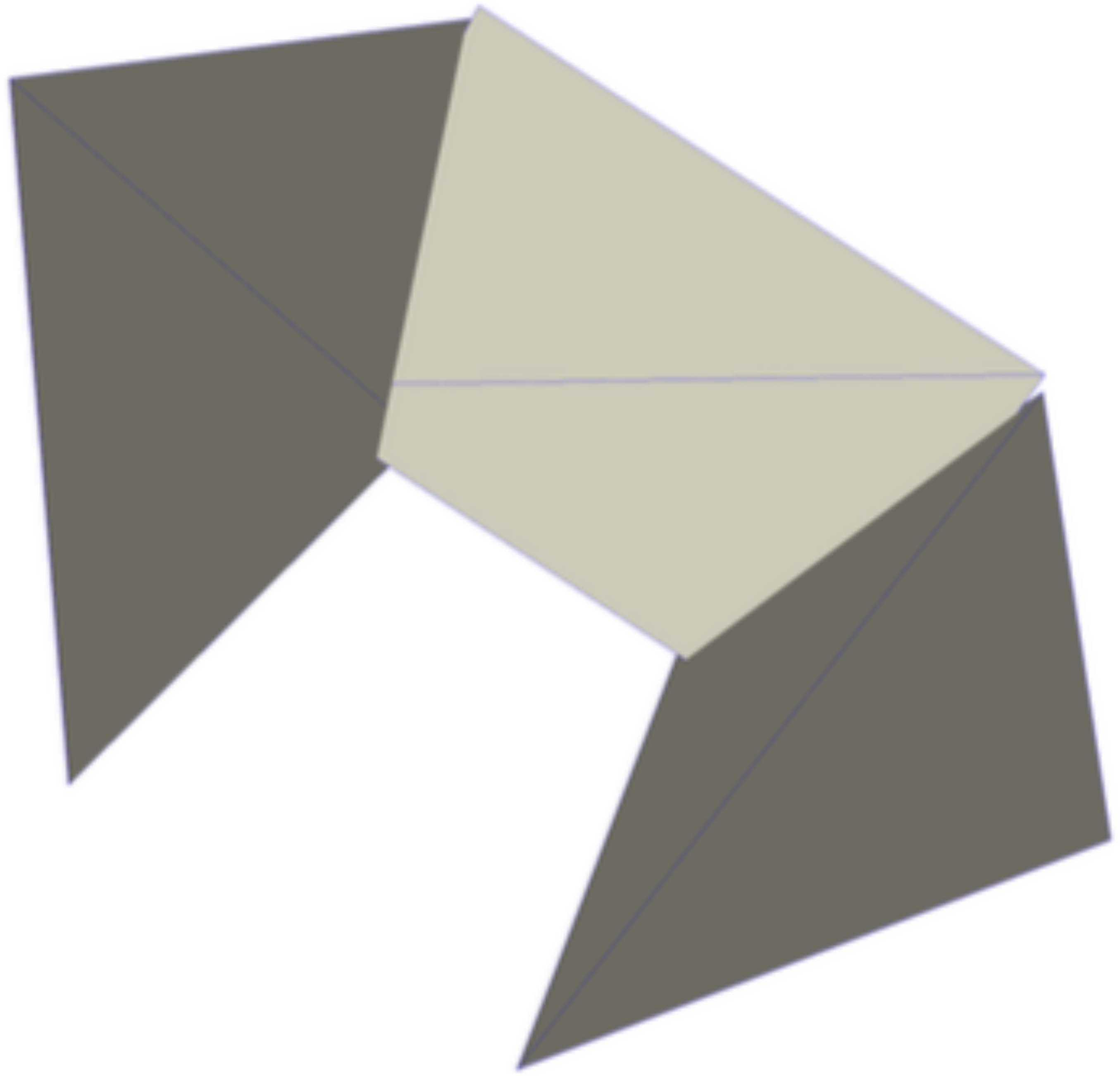
Surface Area

Occlusion Measure

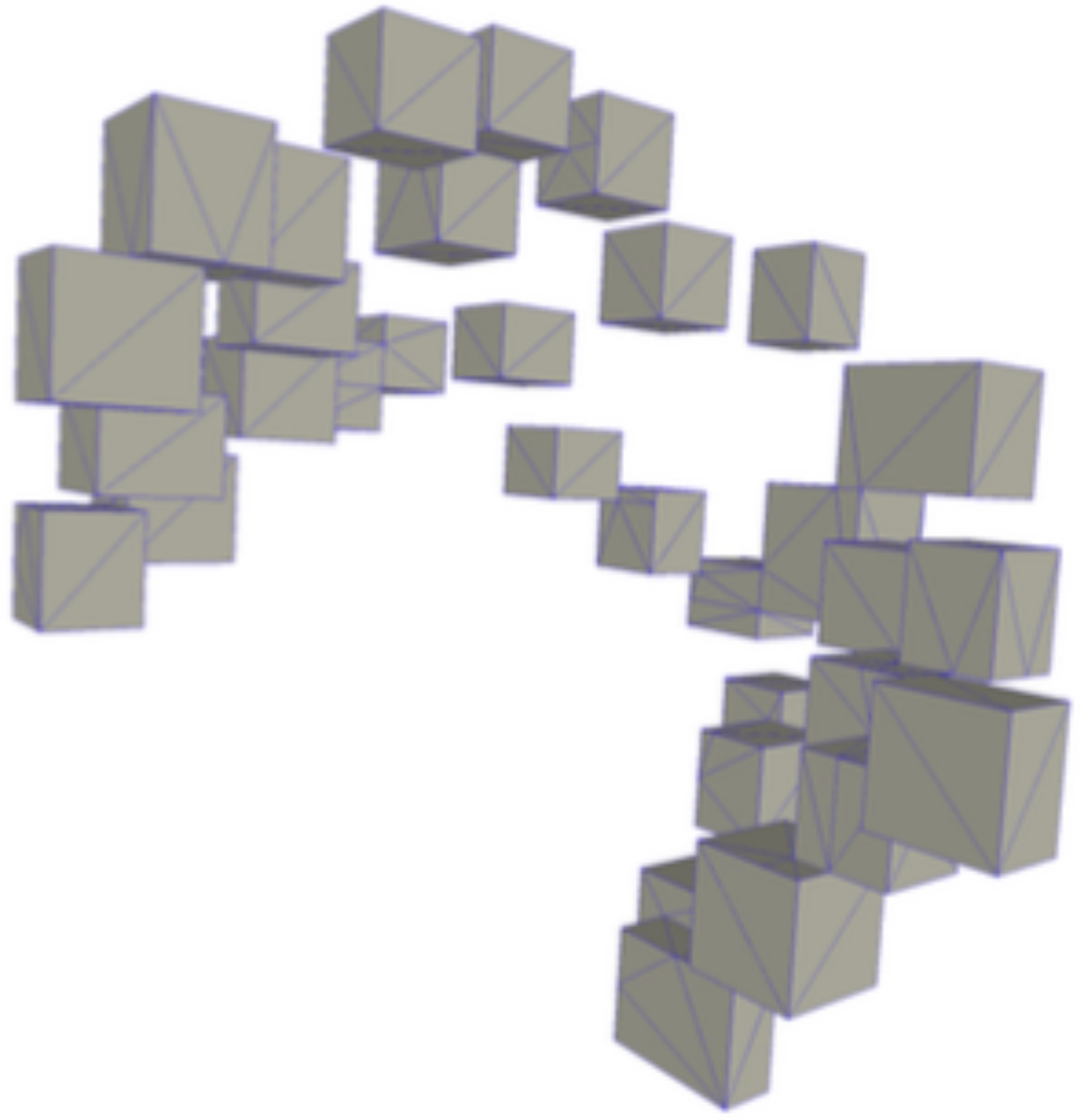
Comparison against Oxel



Input 28 tris

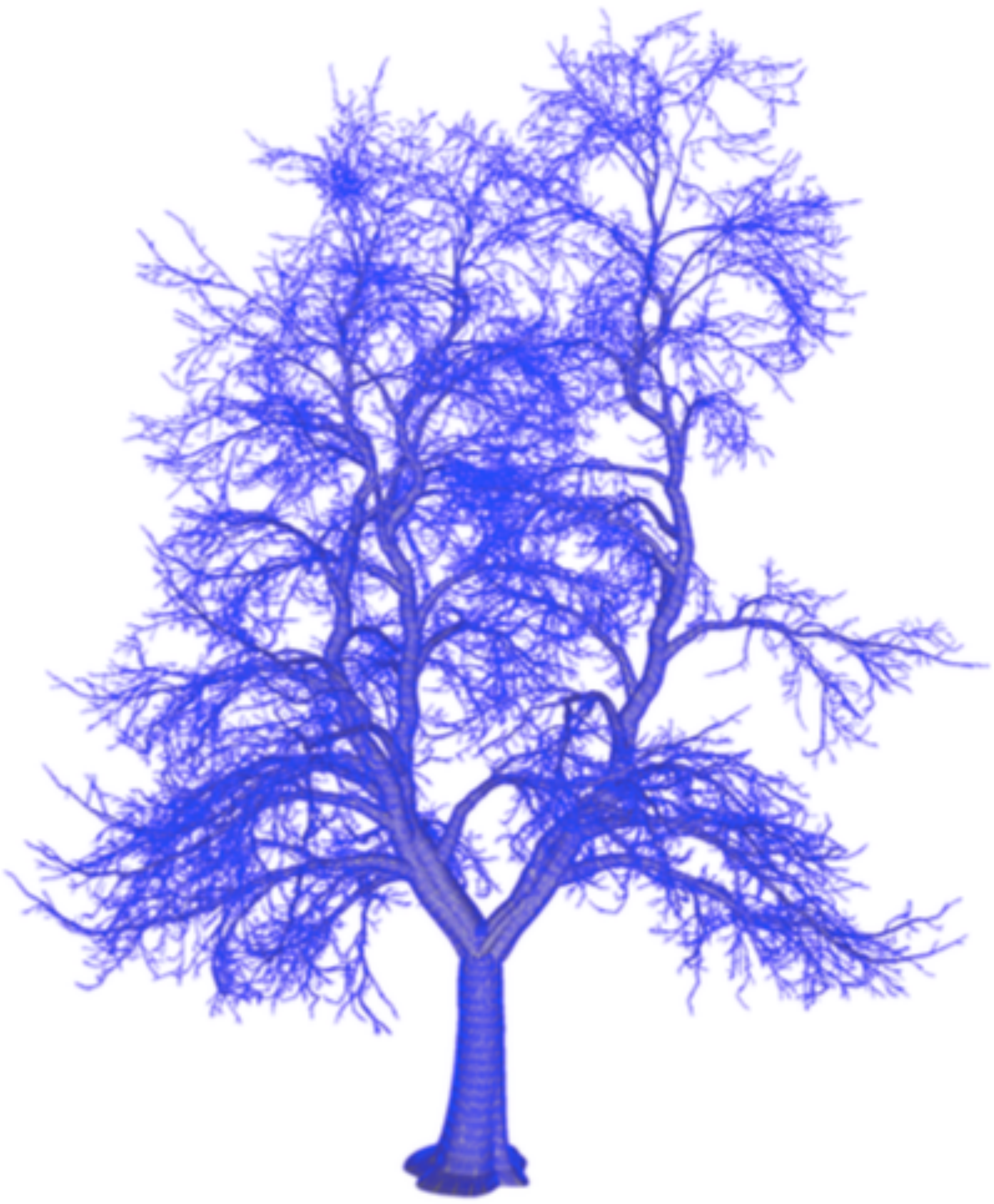


Ours 6 tris

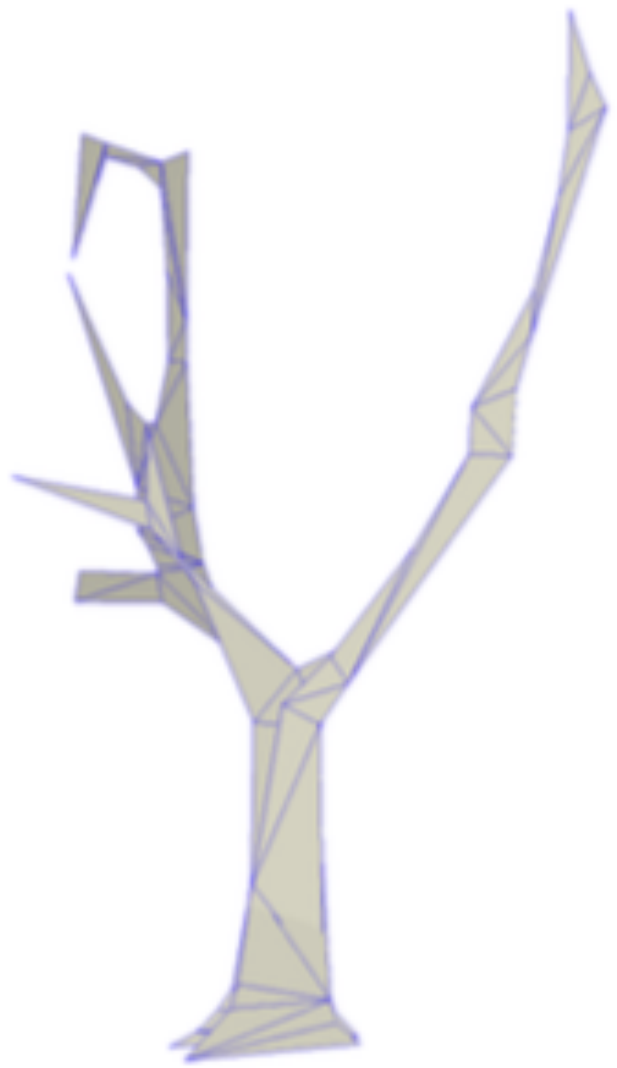


Oxel 509 tris
[Darnell 2011]

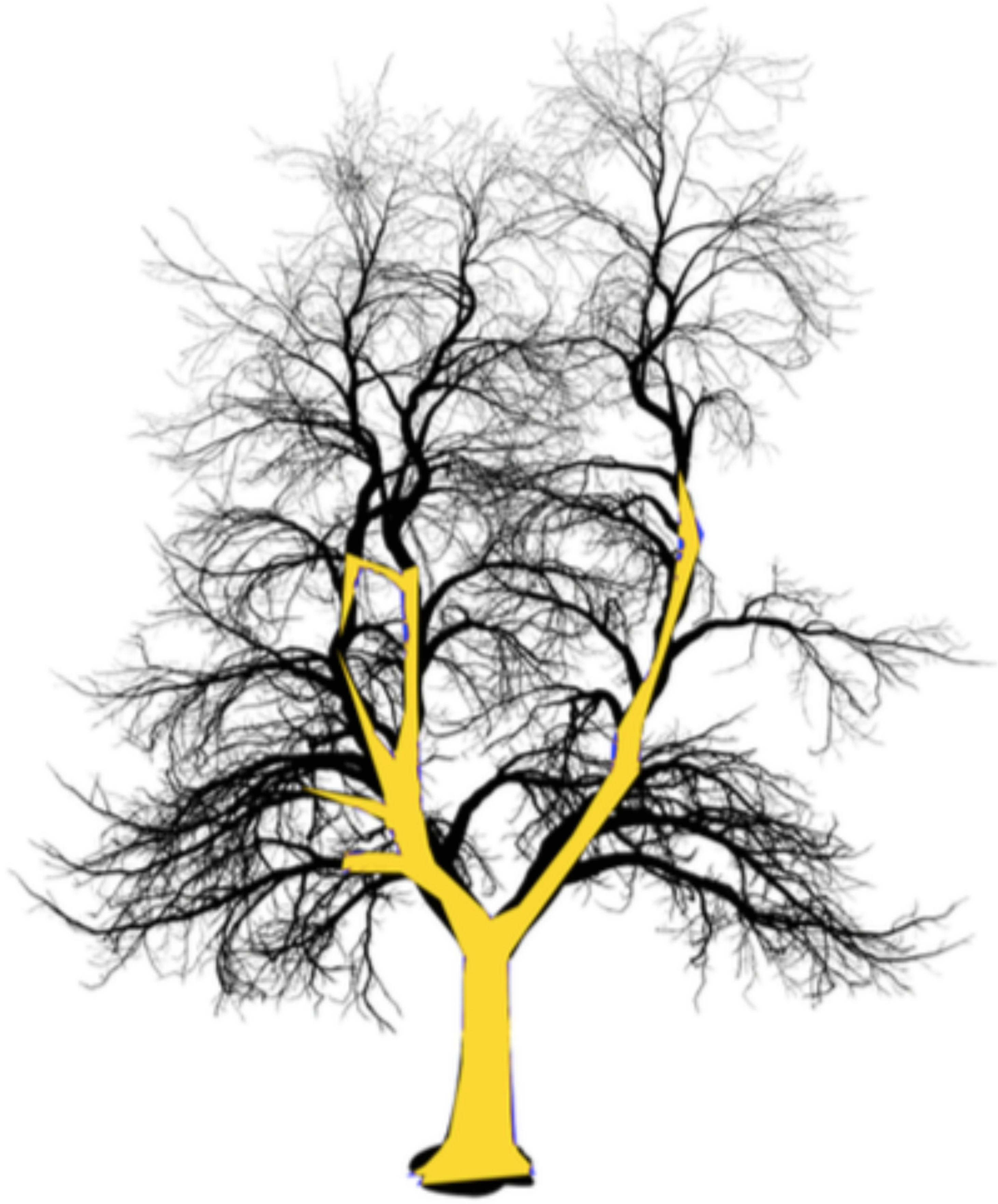
Difficult Input



Input 100K tris



Ours 64 tris

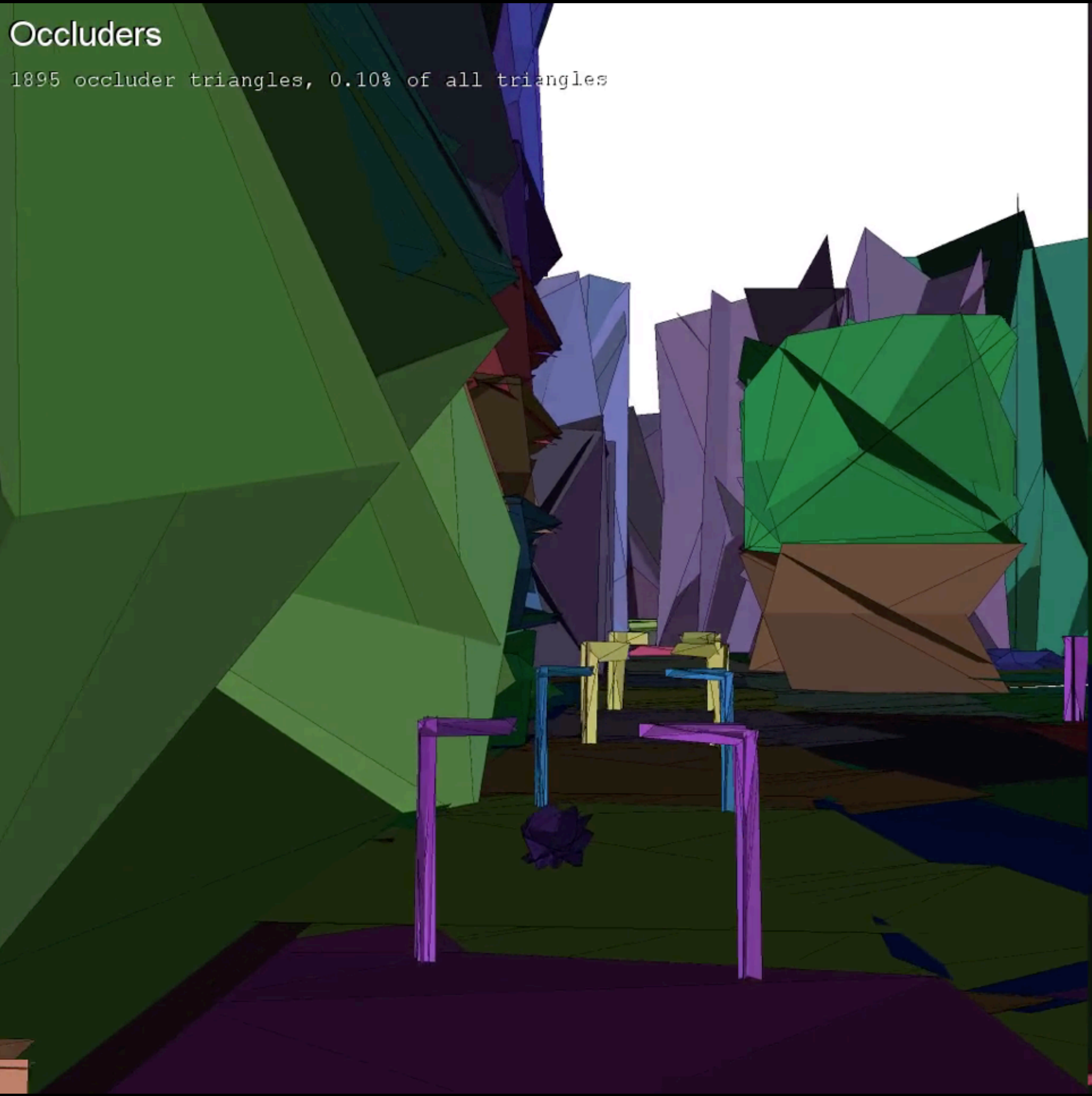


Comparison

Hierarchical extension

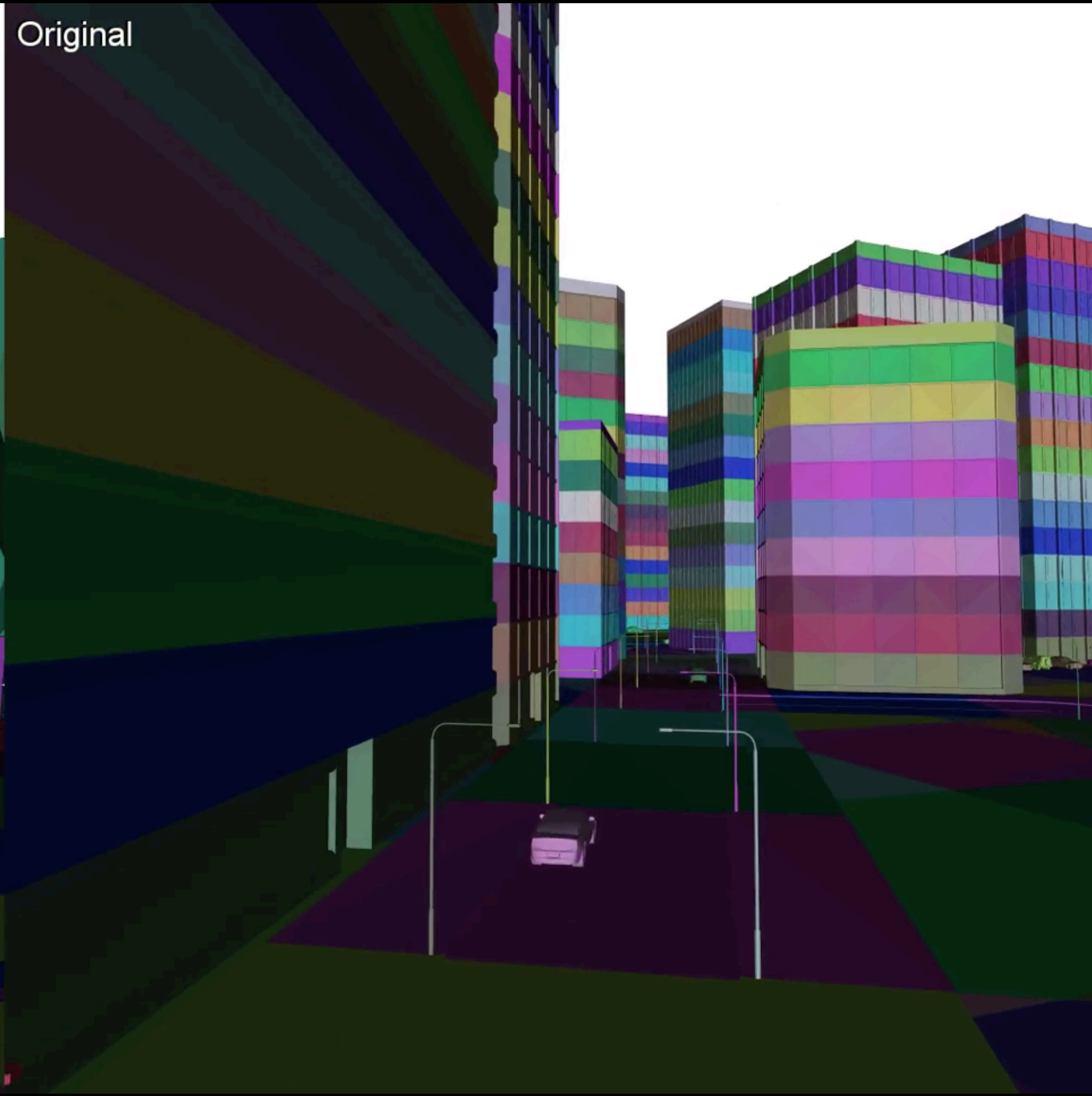
Straightforward extension to handle **large scenes**

Build a BVH over the input geometry and apply the algorithm to **each node separately**



Occluders

1895 occluder triangles, 0.10% of all triangles



Original

Conclusions and Future Work

Principled way to quantify occlusion

— Fast evaluation based on Euclidean Distance Transform

Scalable method for occluder simplification

— Works with general triangle soups

Conclusions and Future Work

Principled way to quantify occlusion

— Fast evaluation based on Euclidean Distance Transform

Scalable method for occluder simplification

— Works with general triangle soups

Could we apply the occlusion measure / simplified occluders to other problems?

— Light ray connections in path tracing? BVH build heuristics?

Thank You!

Acknowledgments

Anonymous reviewers for constructive and thorough feedback

umbra A! Aalto University School of Science

NVIDIA REMEDY

Bounded Approximation Error

Sources of error

— Voxelization error (bounded by voxel size)

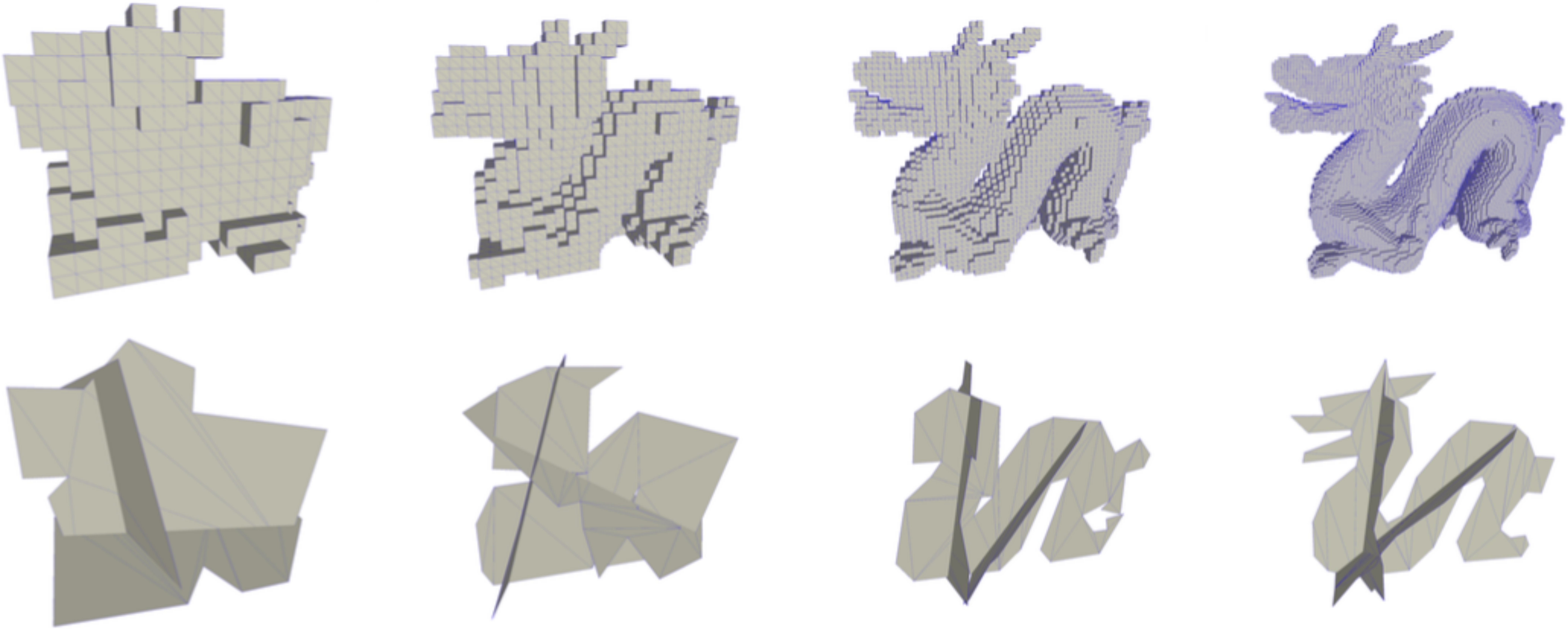
— Rasterization error (bounded by raster resolution)

— Edge loop simplification error (bounded by tolerance)

Single user parameter: Voxel resolution

— Raster resolution and edge loop simplification set accordingly

Effect of Scale-Sensitive Discretization



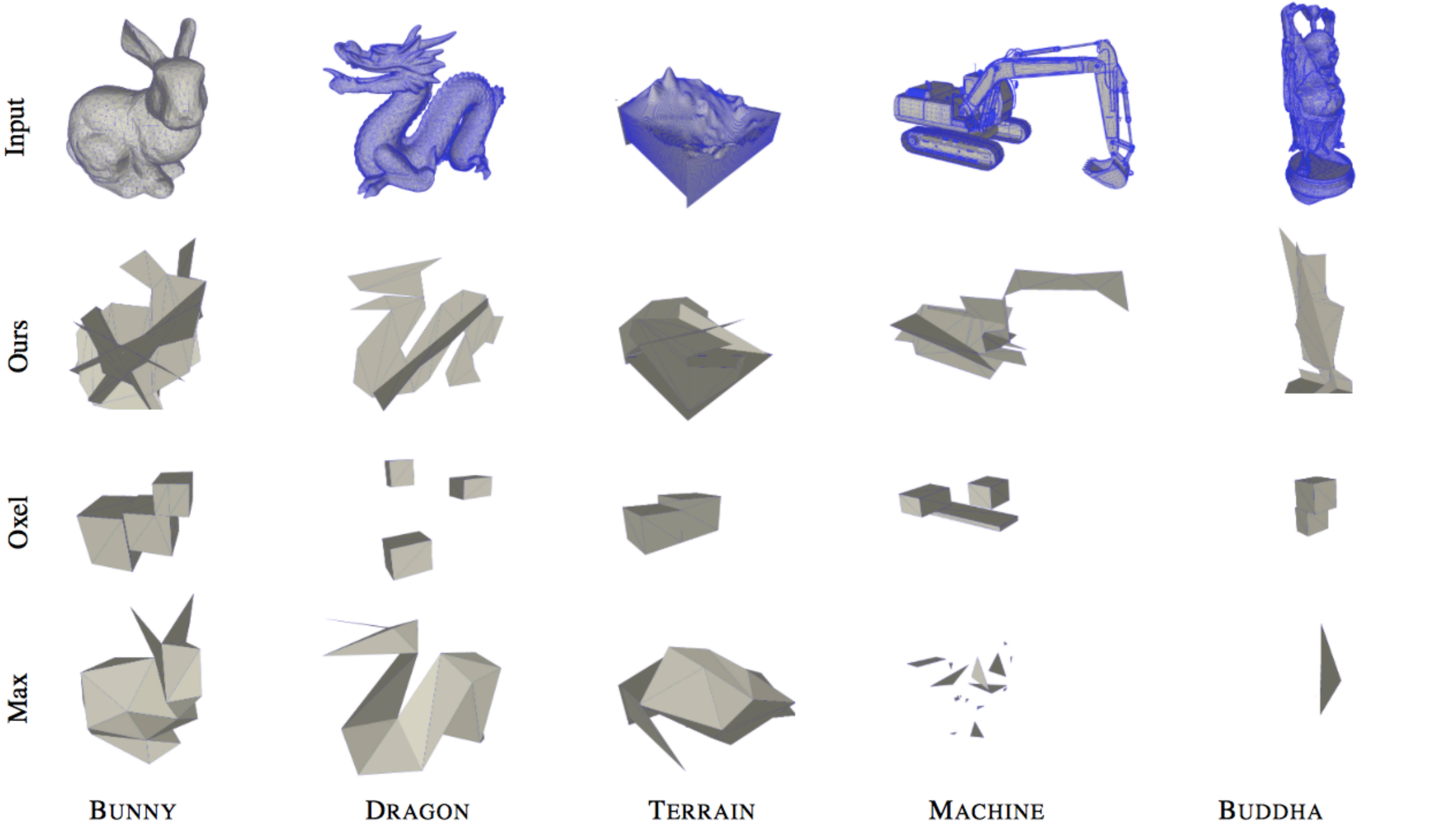
16x16x16

32x32x32

64x64x64

128x128x128

Comparison to Other Methods



Fast Evaluation of the Occlusion Measure

Directional occlusion is connected to **Euclidean Distance Transform**

Gives a practical way to calculate the occlusion measure

Hierarchical extension

Input
Hierarchical Occluder