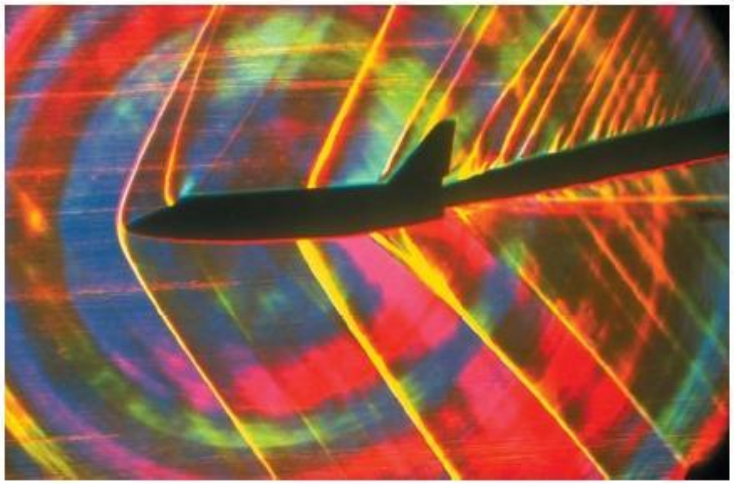
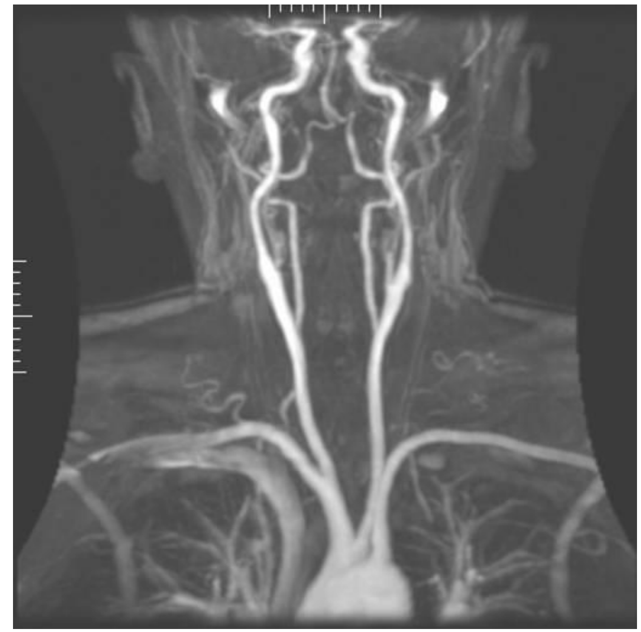
Isosurfaces Over Simplicial Partitions of Multiresolution Grids

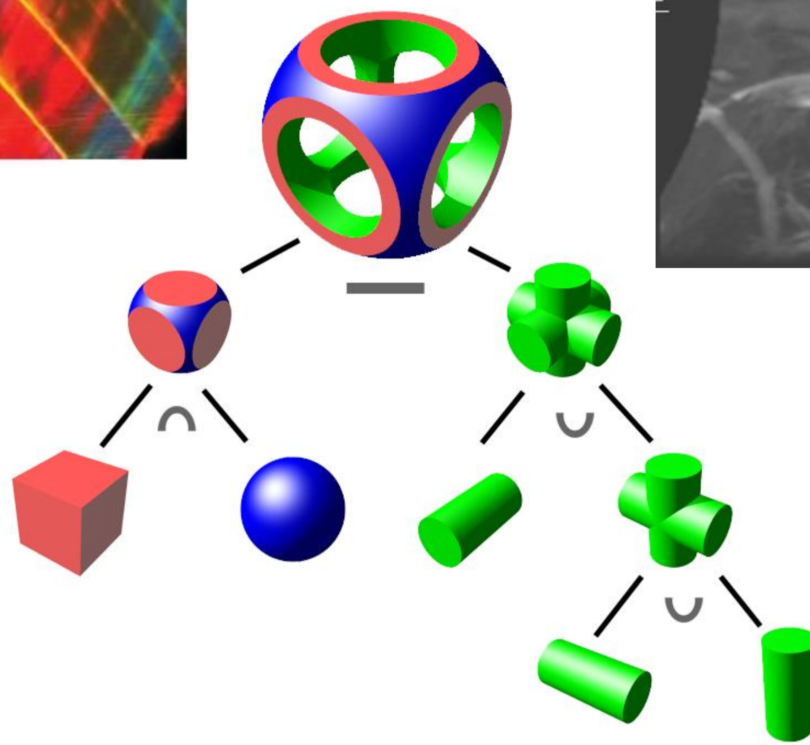
Josiah Manson and Scott Schaefer

Texas A&M University

Motivation: Uses of Isosurfaces







Motivation: Goals

- Sharp features
- Thin features
- Arbitrary octrees
- Manifold / Intersection-free

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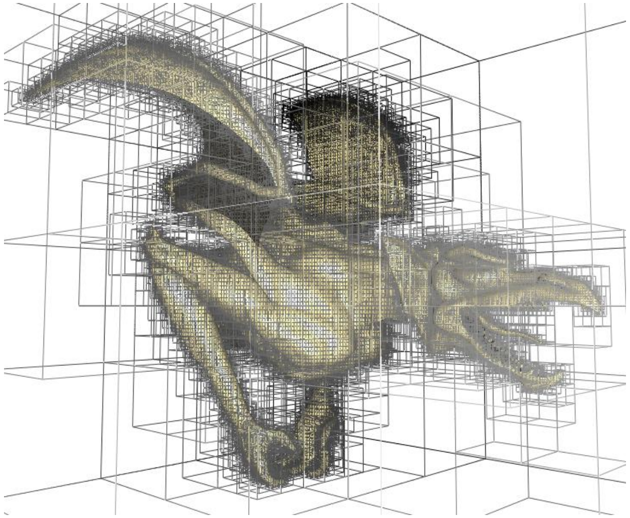

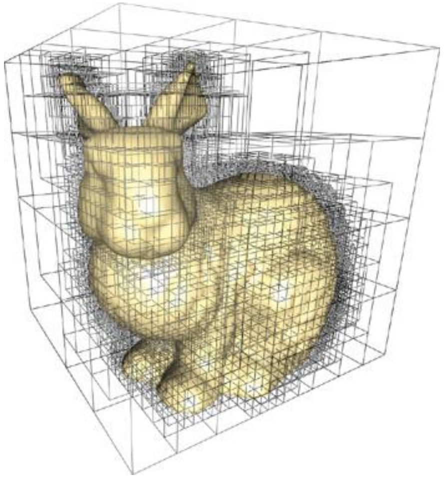

Octree Textures on the GPU [Lefebvre et al. 2005]

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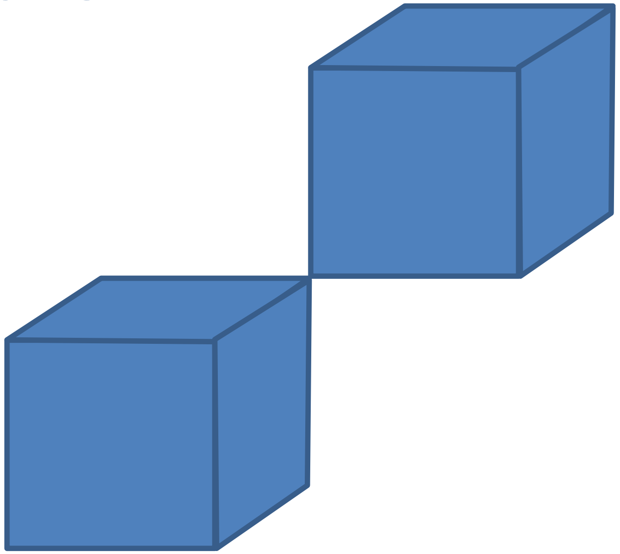

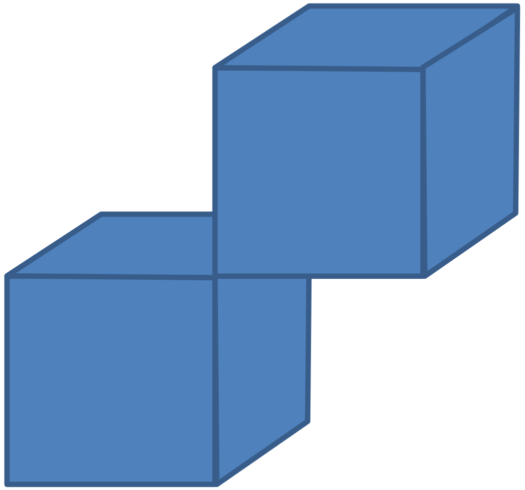

Related Work

- Dual Contouring [Ju et al. 2002]
- Intersection-free Contouring on an Octree Grid [Ju 2006]
- Dual Marching Cubes [Schaefer and Warren 2004]
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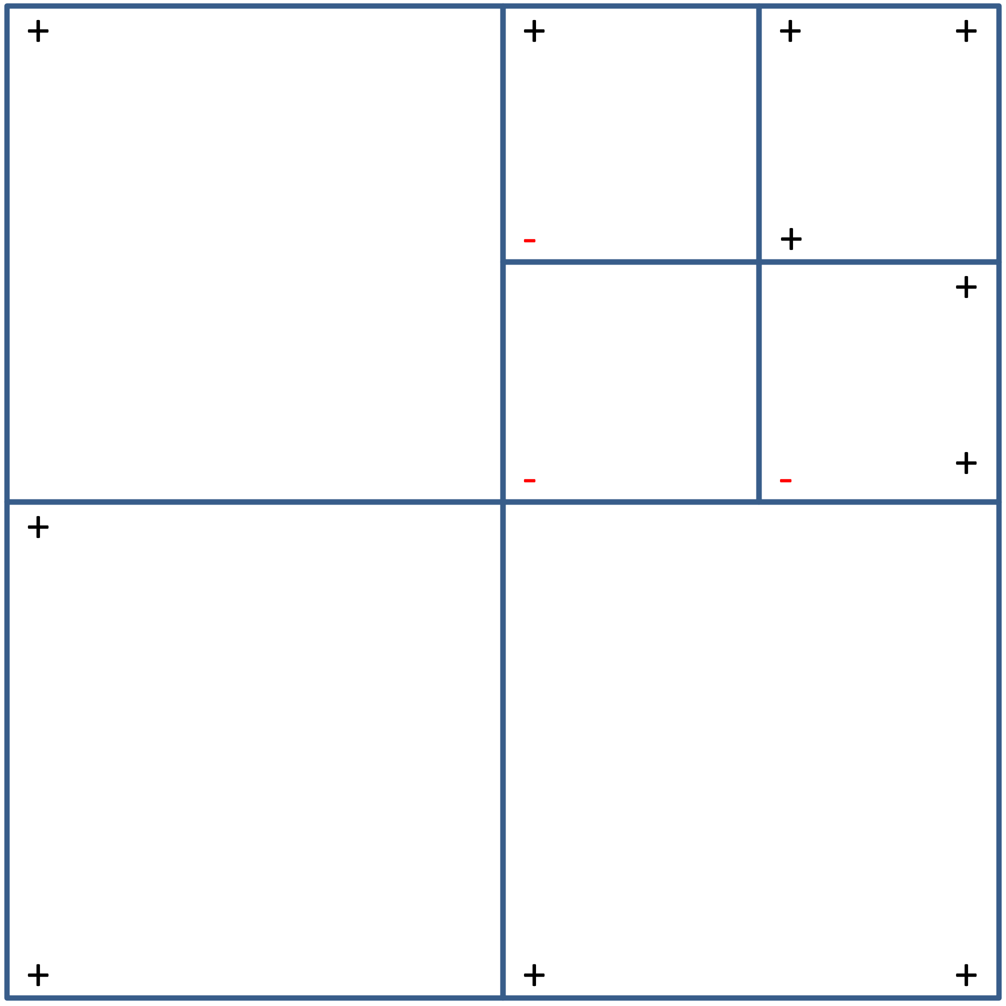
Dual Contouring



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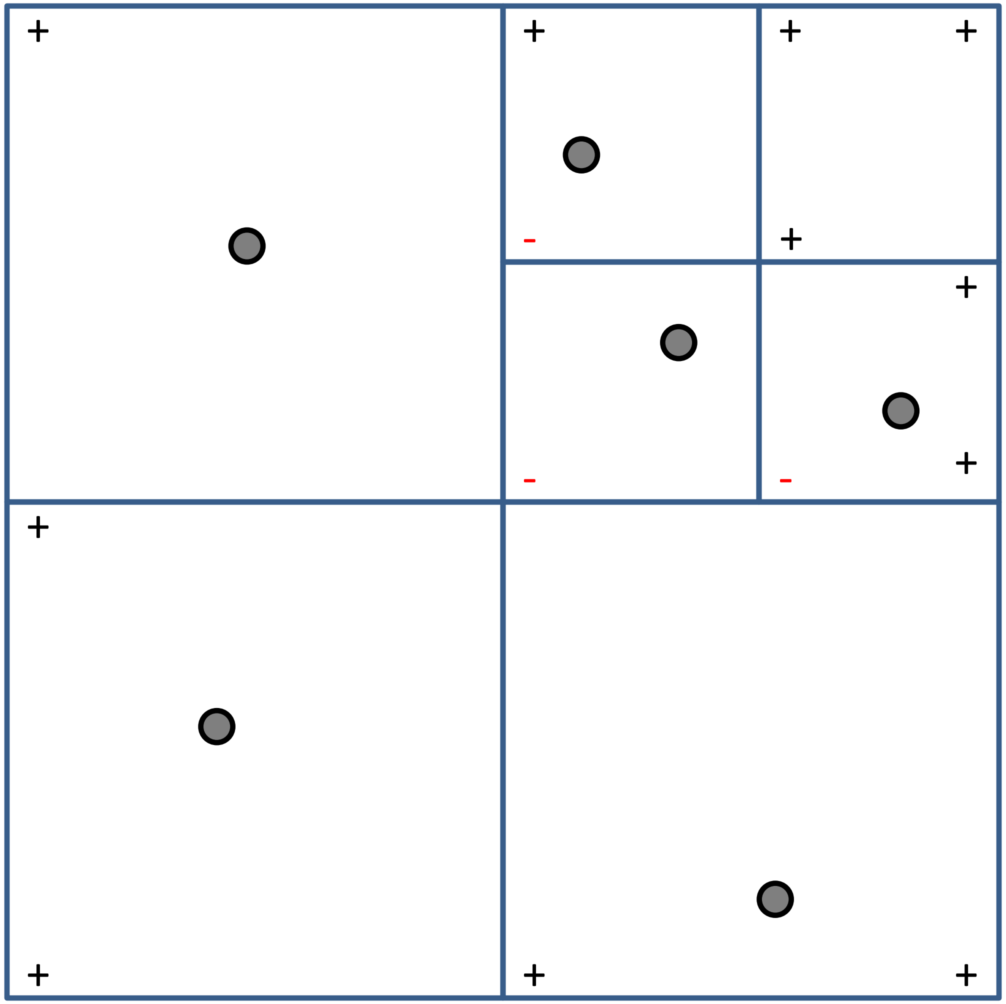

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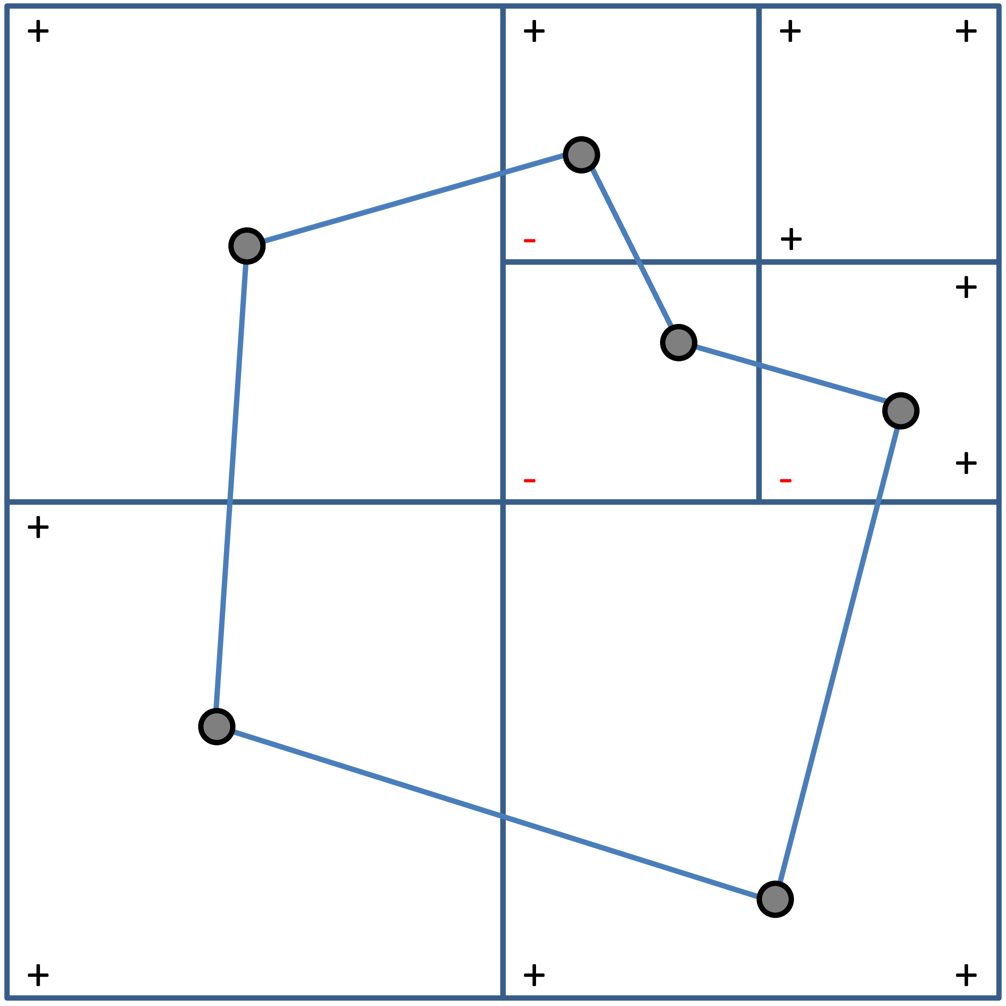

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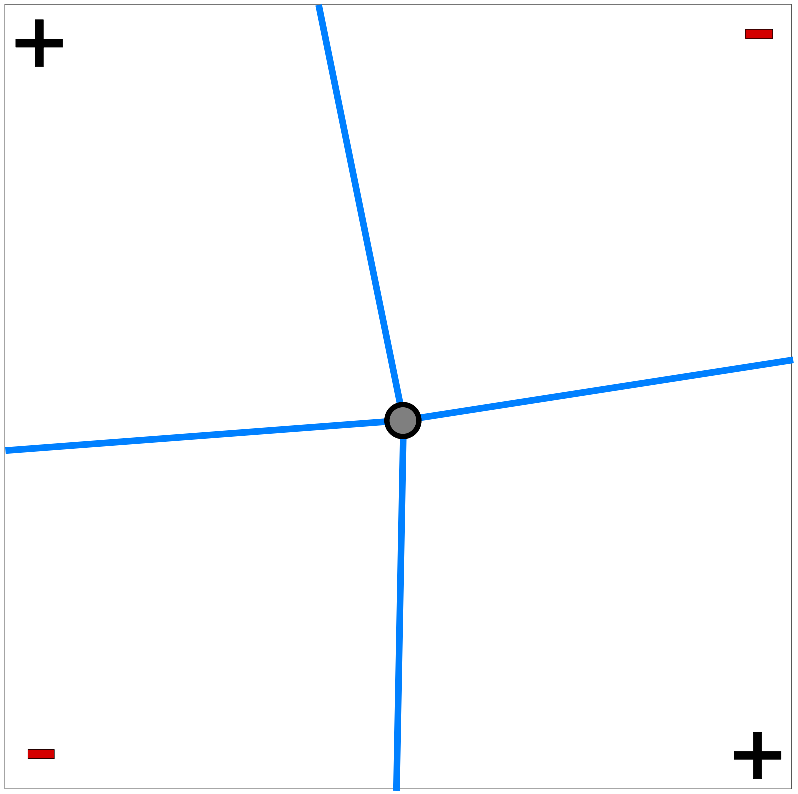

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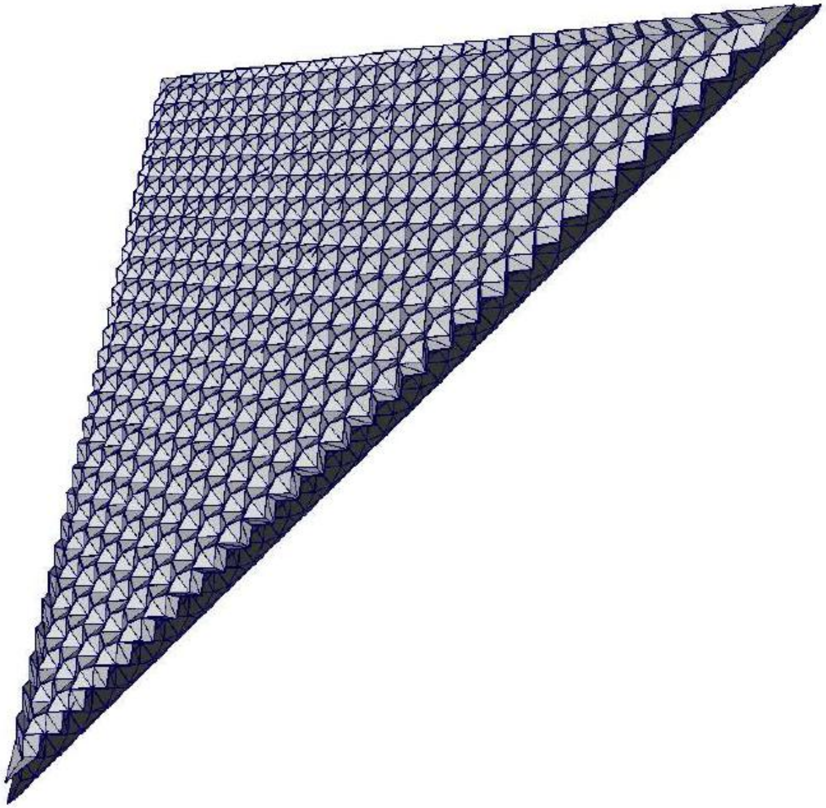

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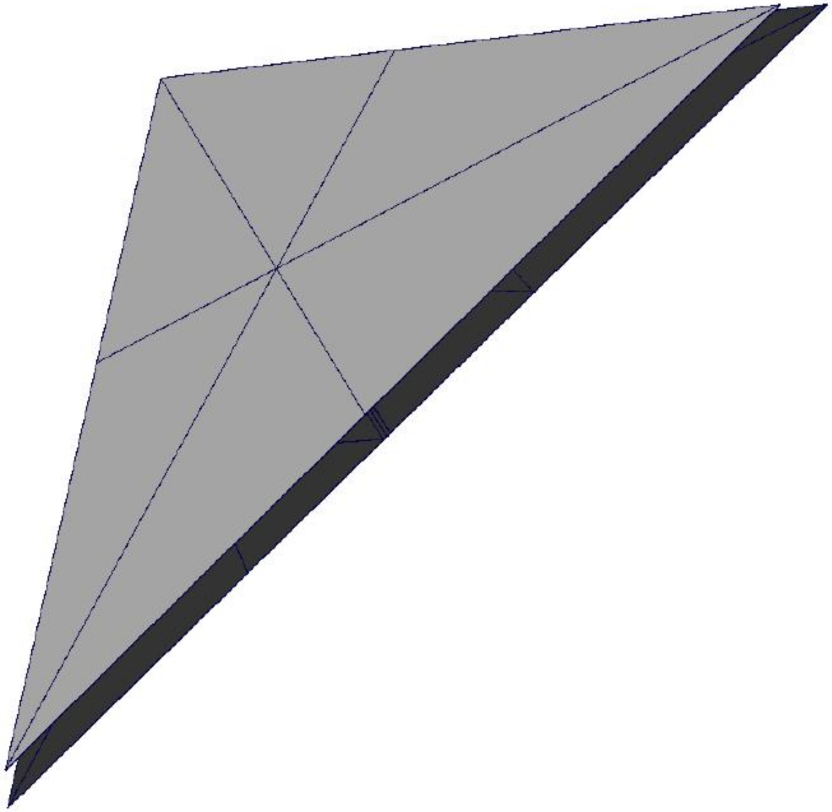
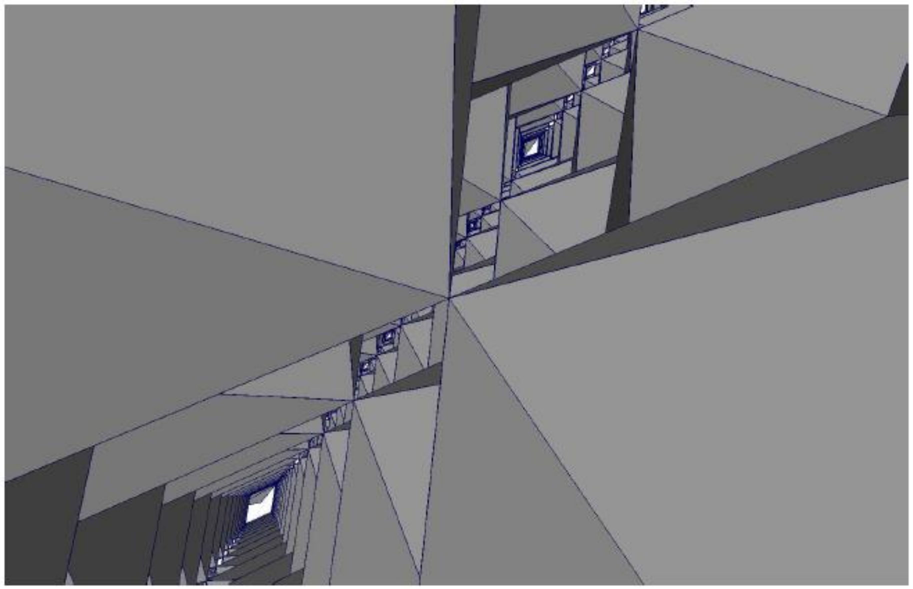


Our method

Dual Contouring



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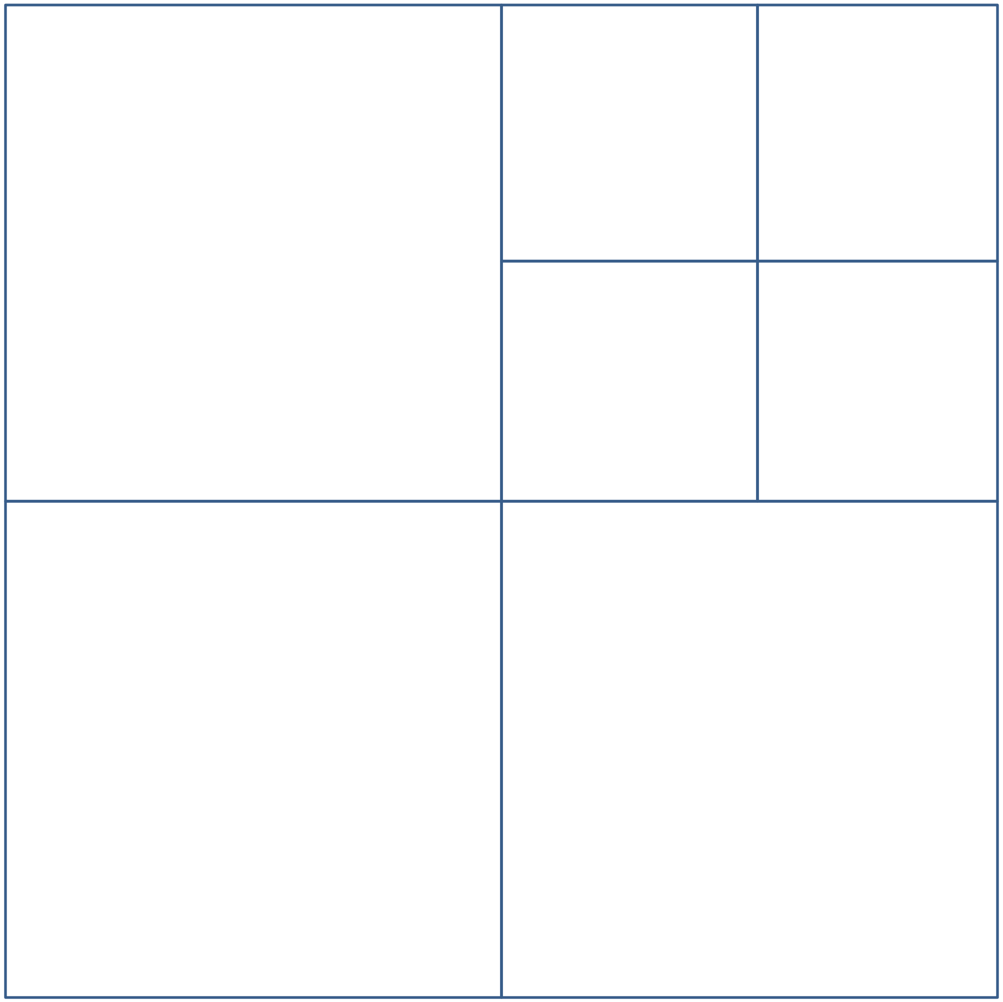

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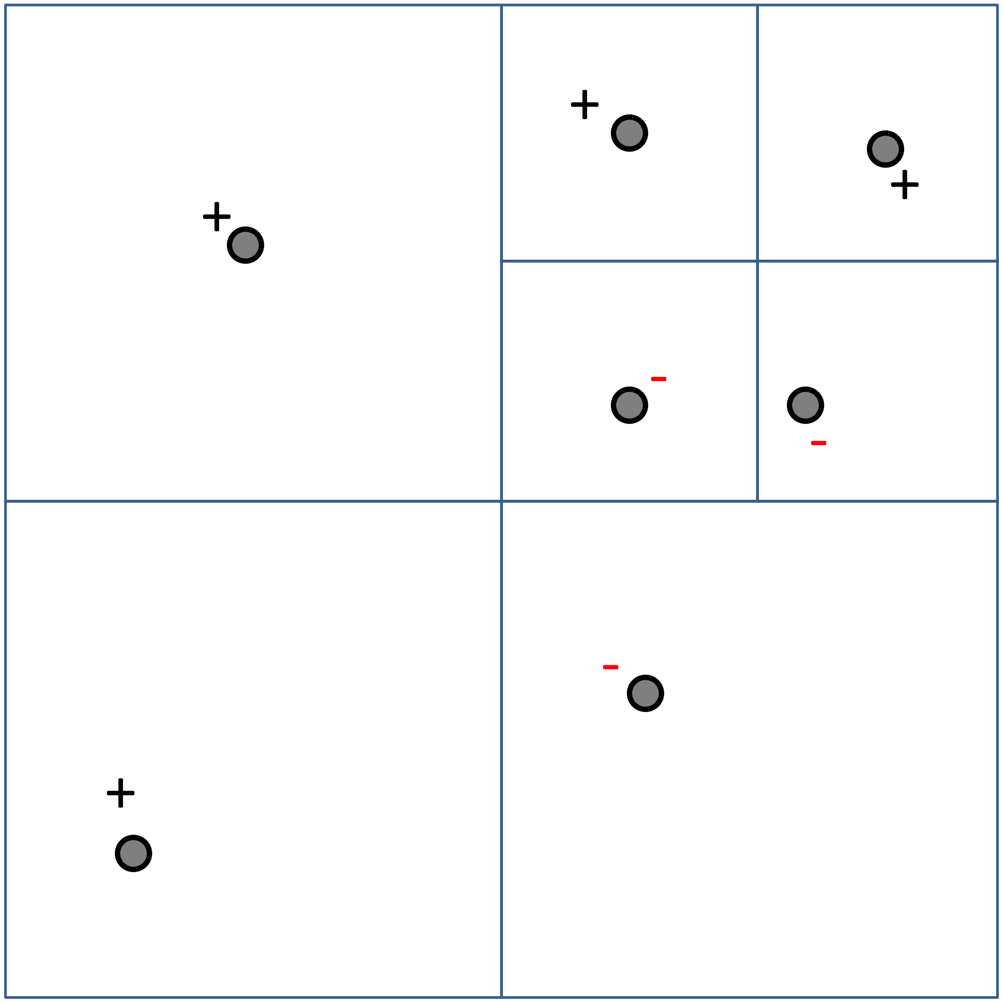

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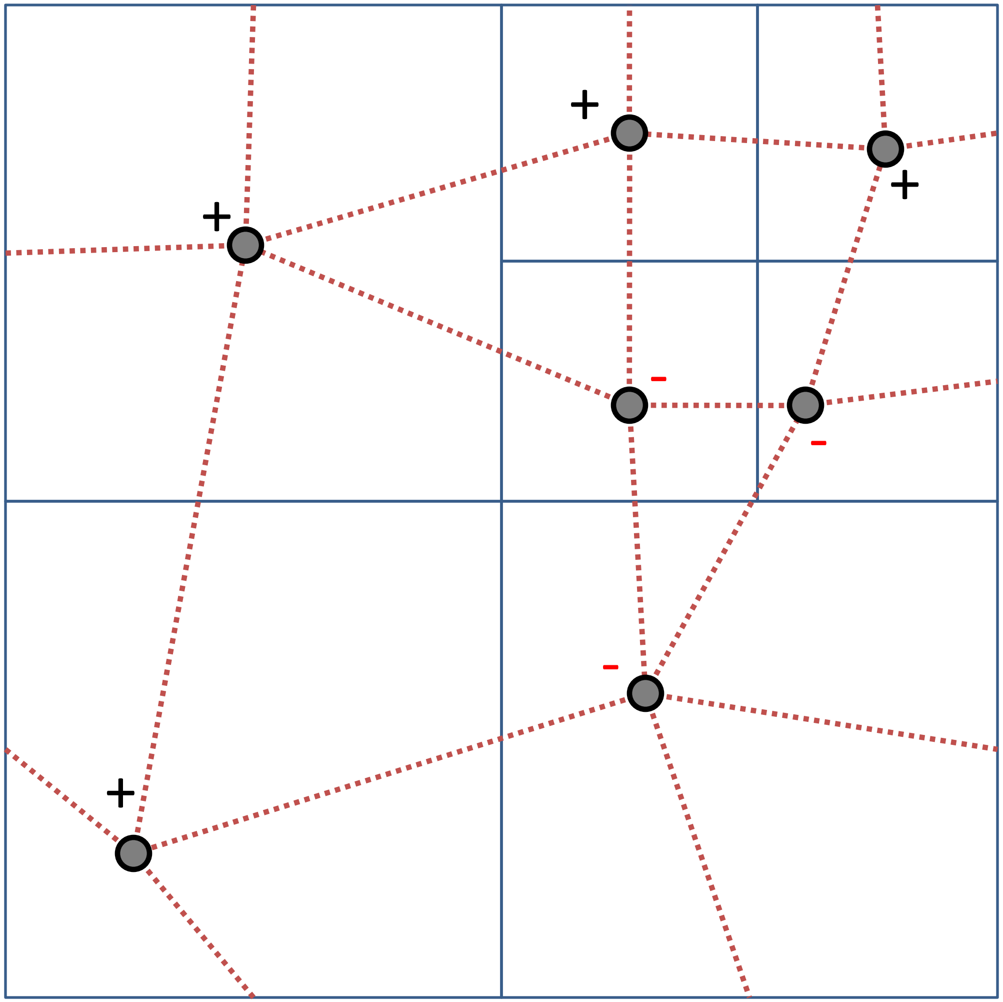

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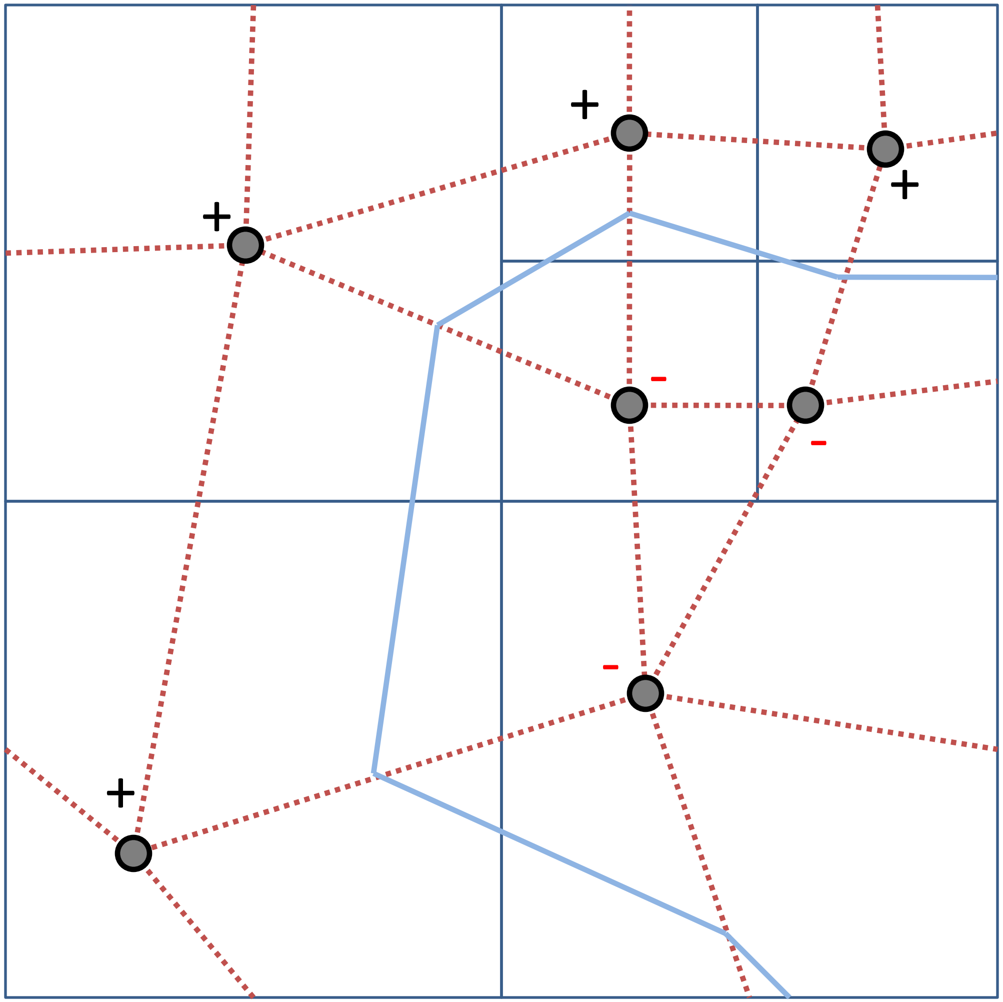

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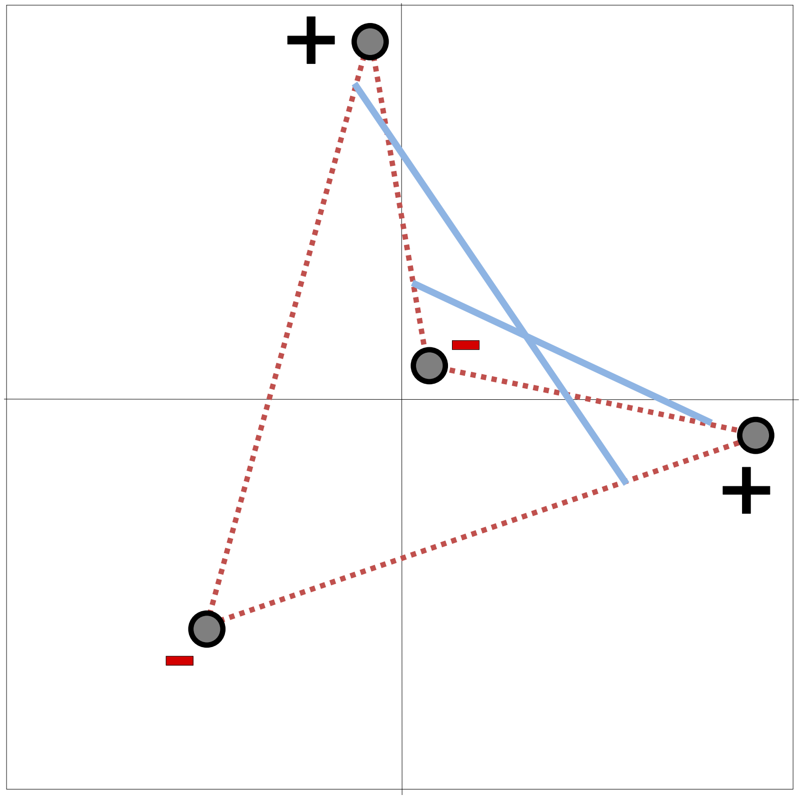

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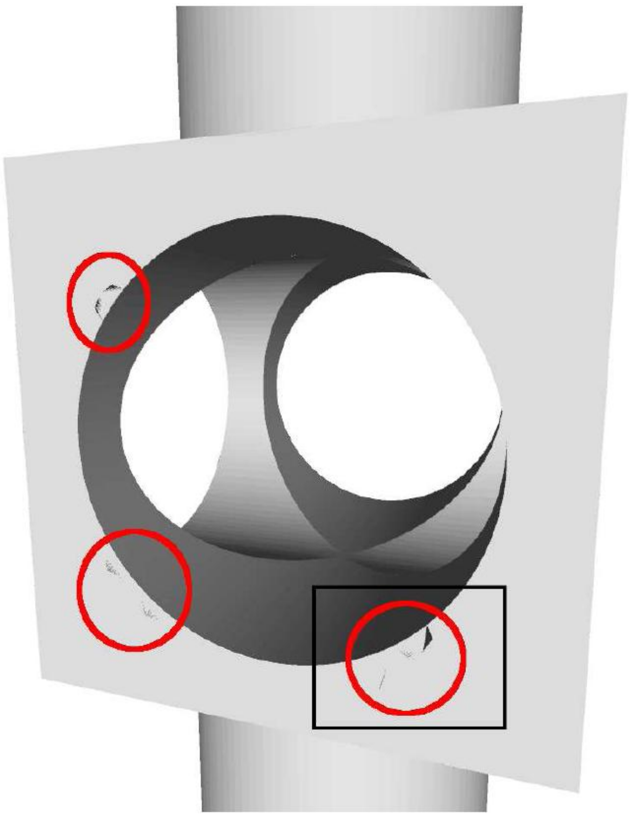
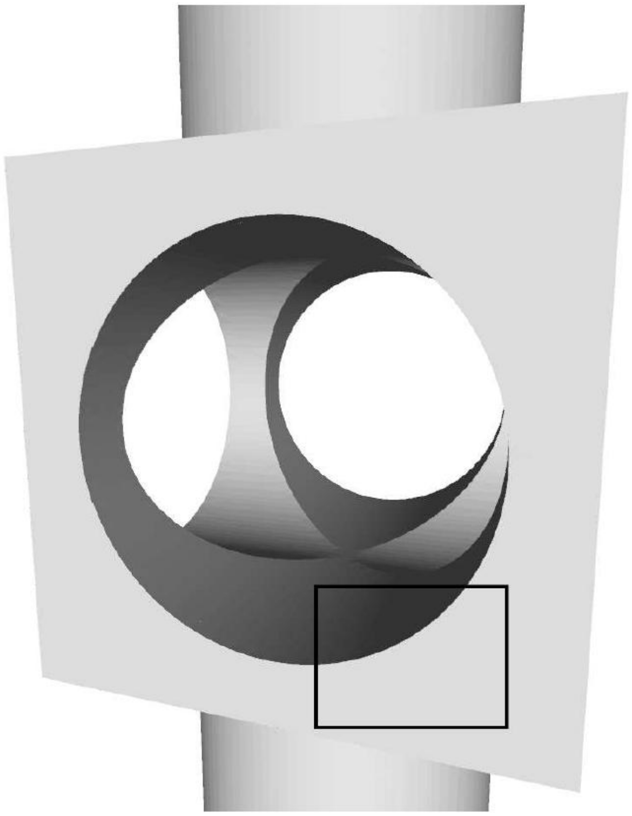


Dual Marching Cubes
[Schaefer and Warren 2004]



Our method

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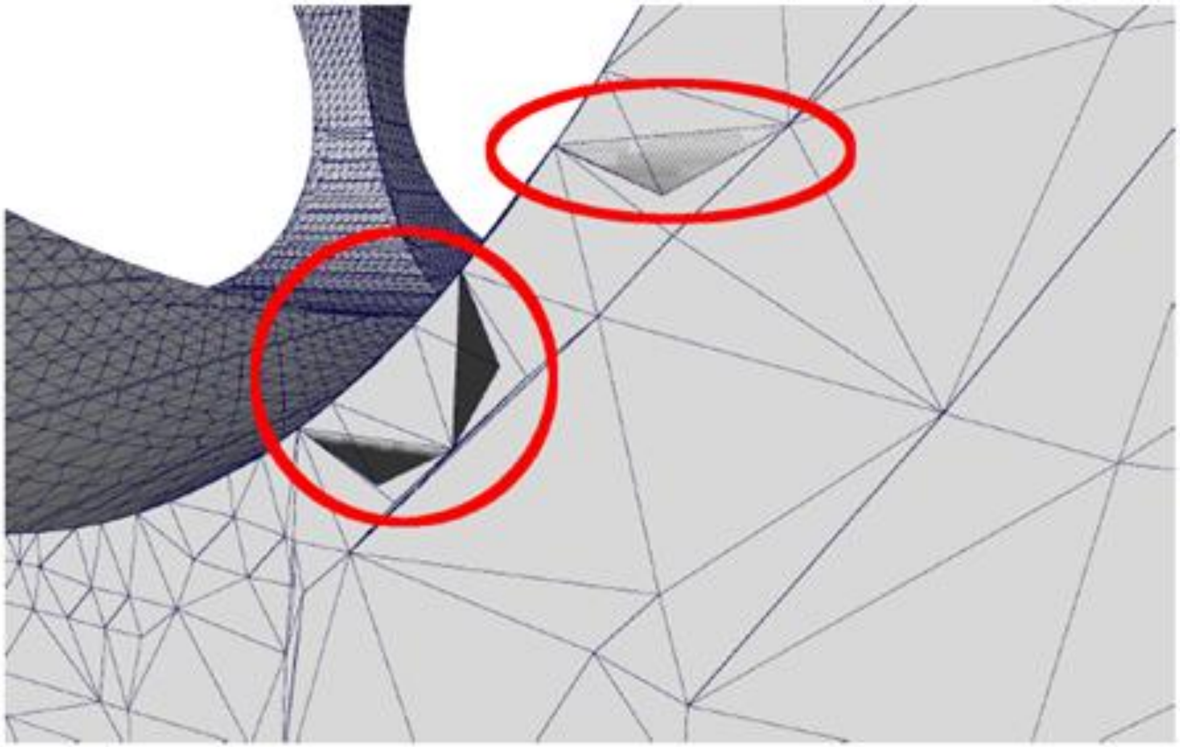

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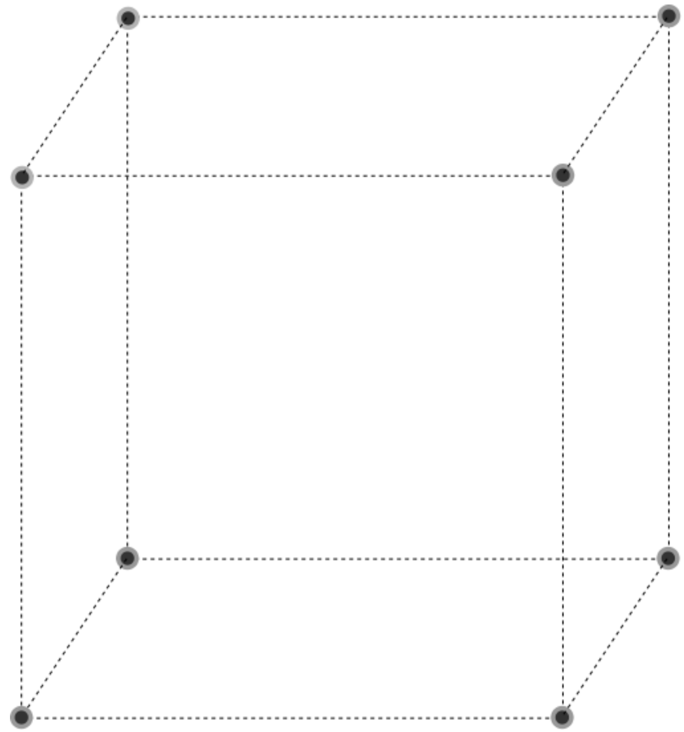
Our Method Overview

- Create vertices dual to every minimal edge, face, and cube
- Partition octree into 1-to-1 covering of tetrahedra
- Marching tetrahedra creates manifold surfaces
- Improve triangulation while preserving topology

Terminology

- Cells in Octree
  - Vertices are 0-cells
  - Edges are 1-cells
  - Faces are 2-cells
  - Cubes are 3-cells
- Dual Vertices
  - Vertex dual to each m-cell
  - Constrained to interior of cell



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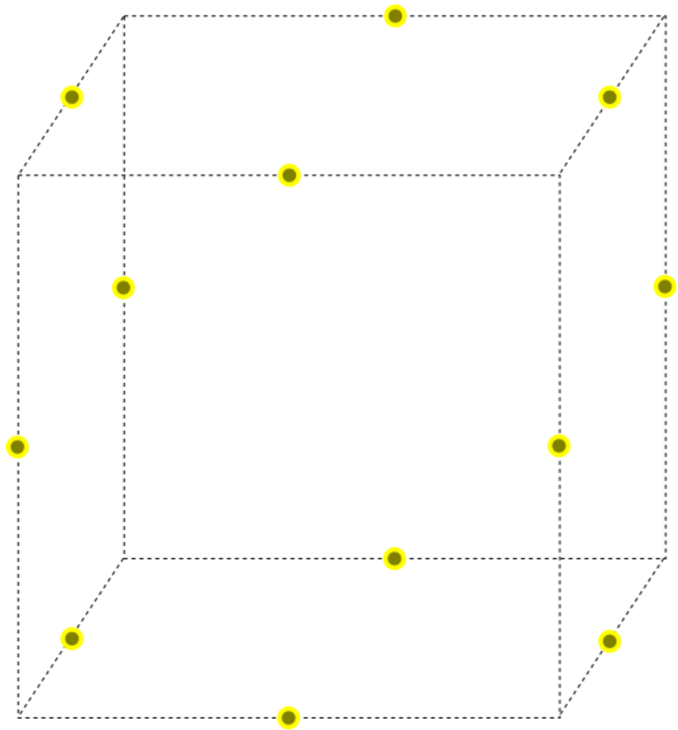

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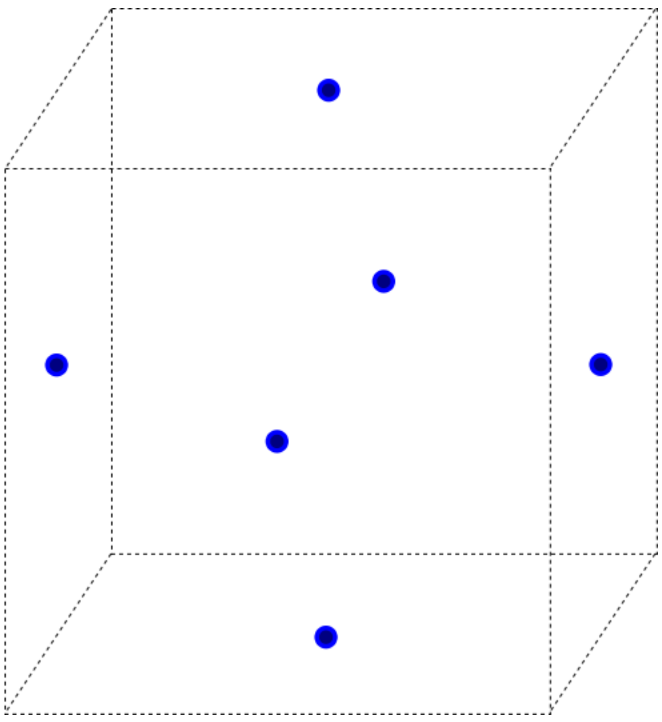

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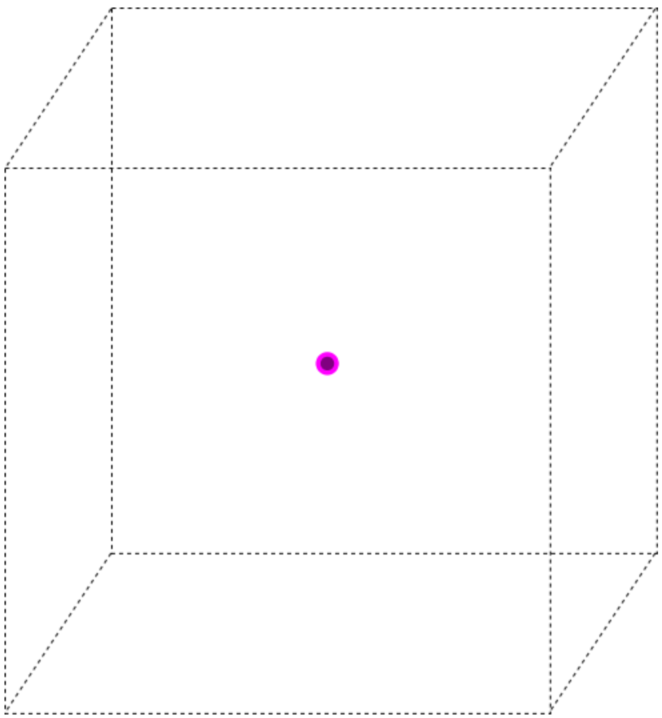

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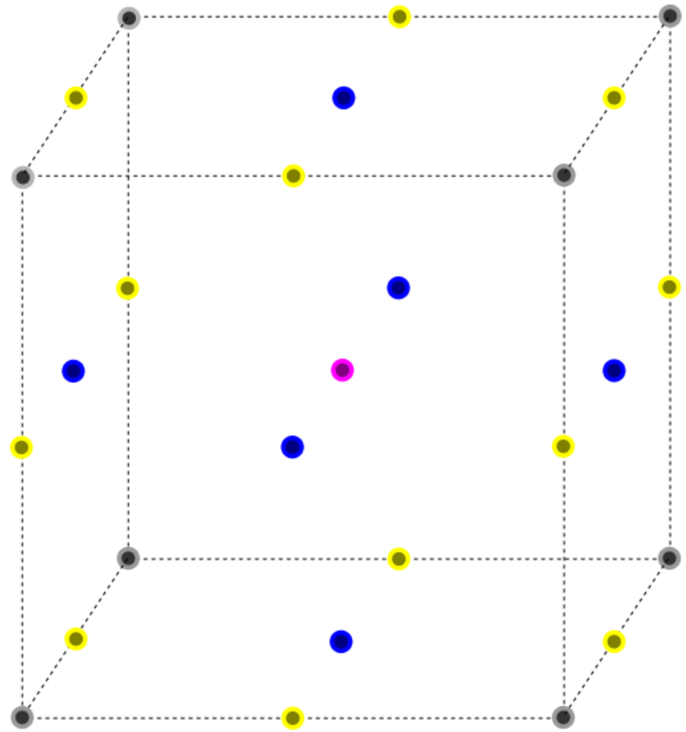
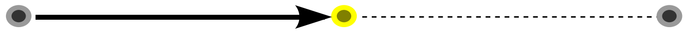


Our Partitioning of Space

- Start with vertex

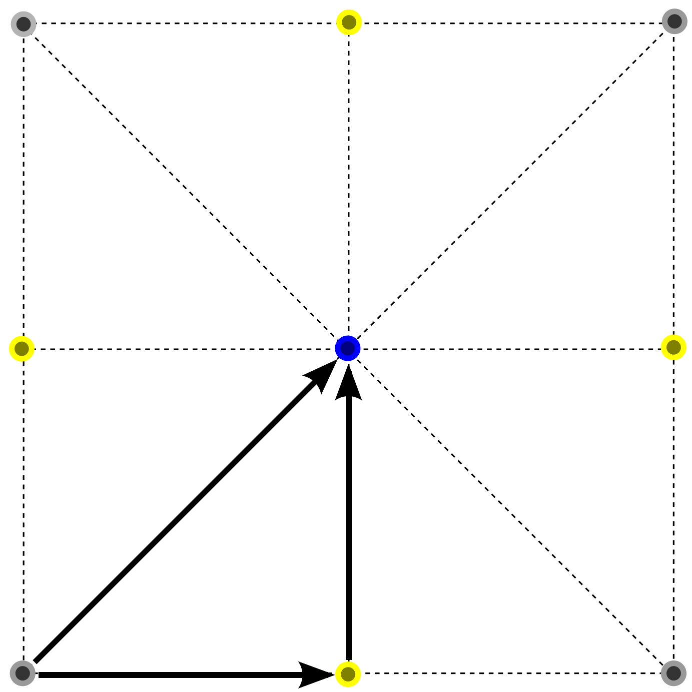
Our Partitioning of Space

- Build edges



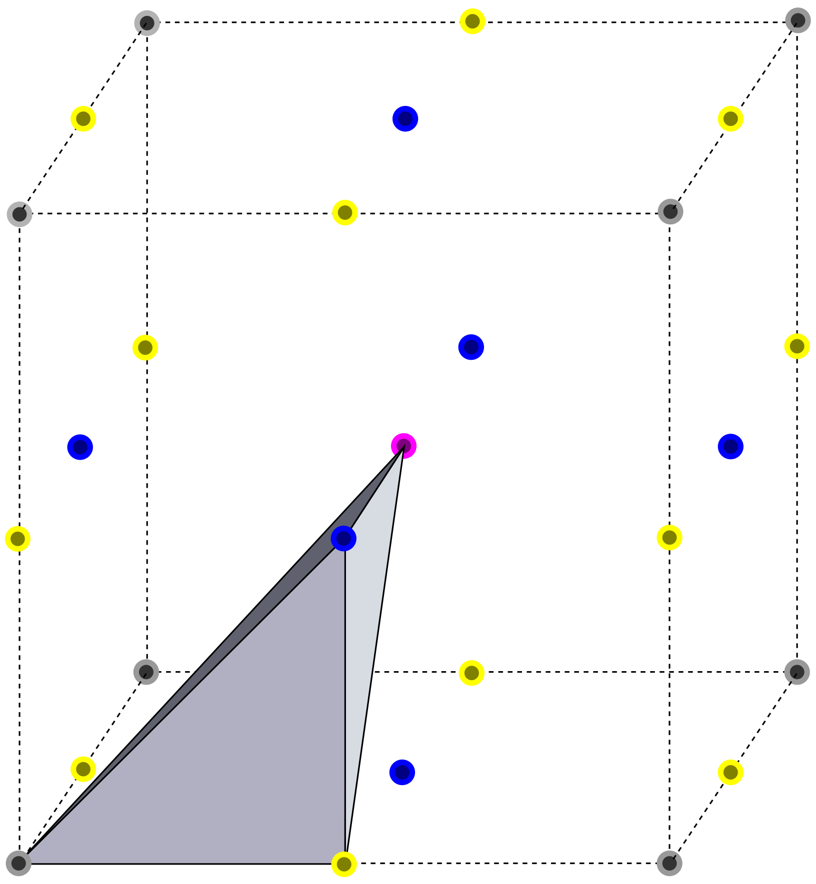
Our Partitioning of Space

- Build faces

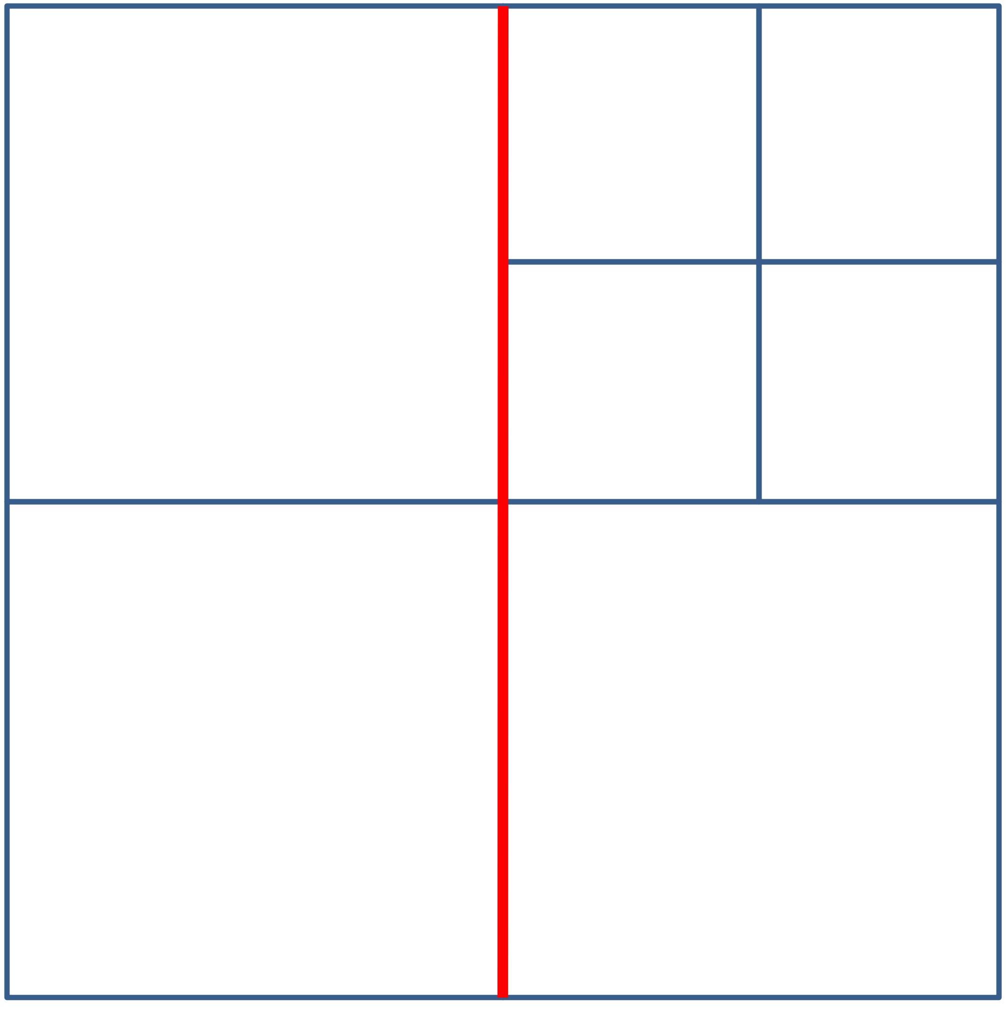


Our Partitioning of Space

- Build cubes



Minimal Edge (1-Cell)



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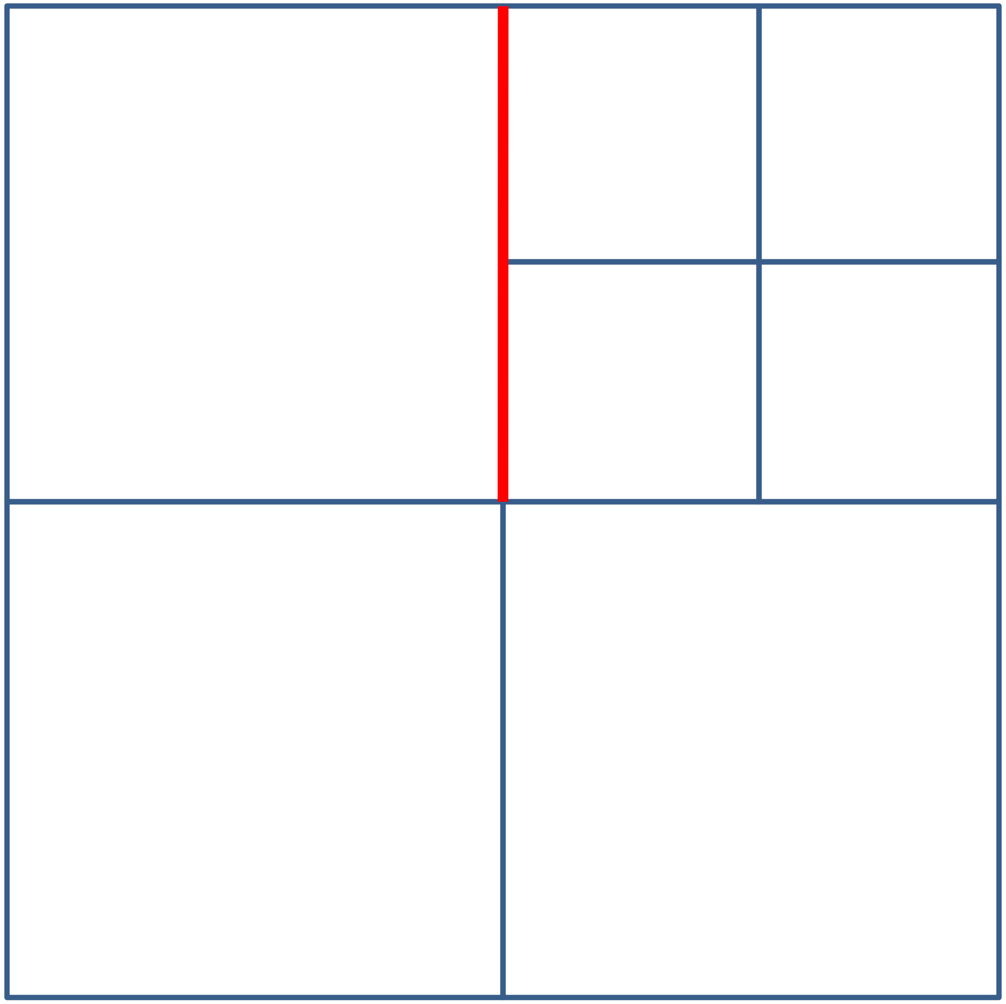

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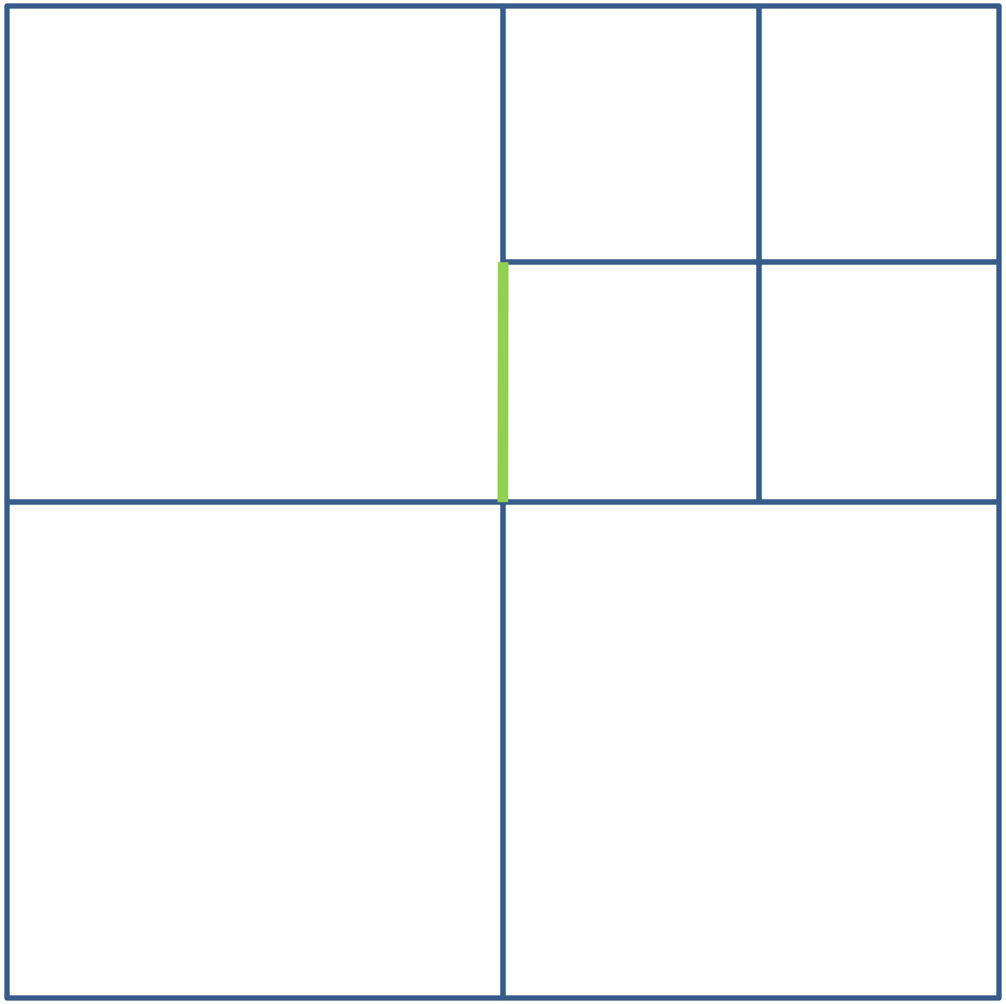

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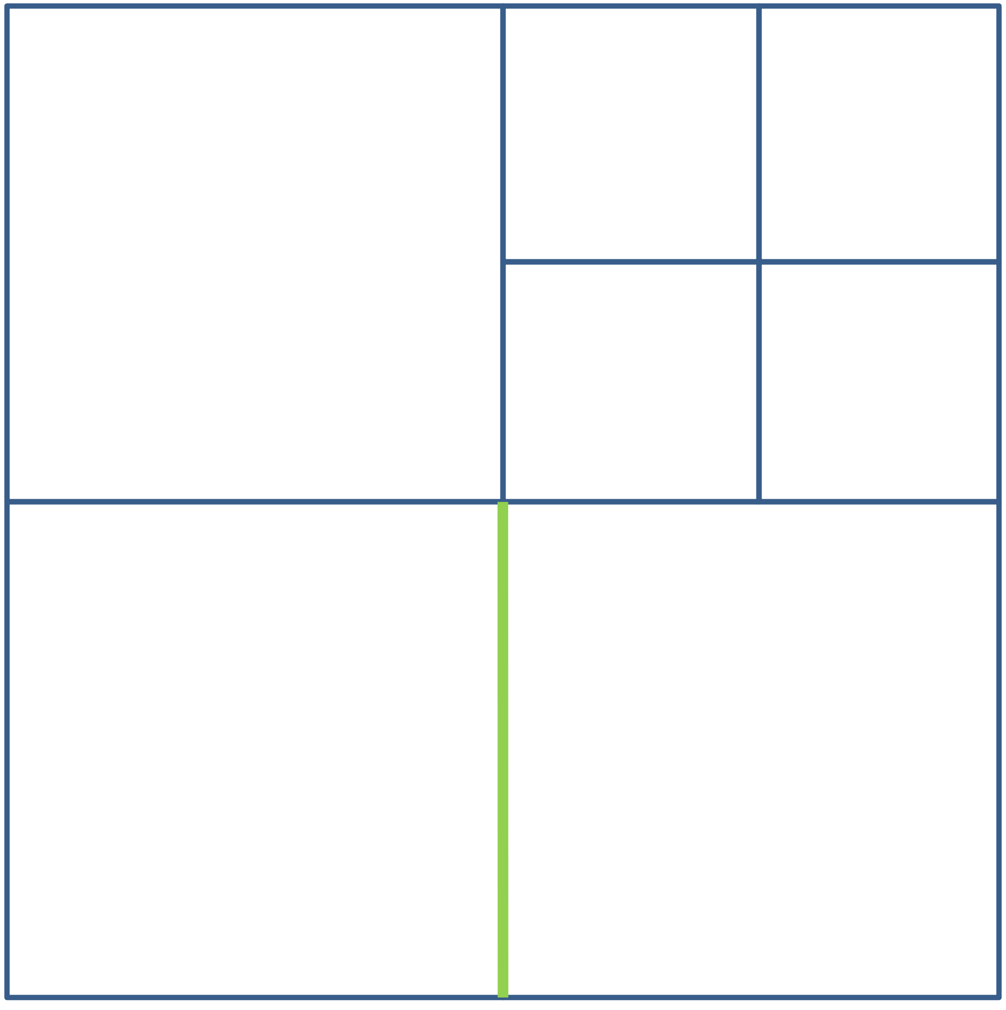
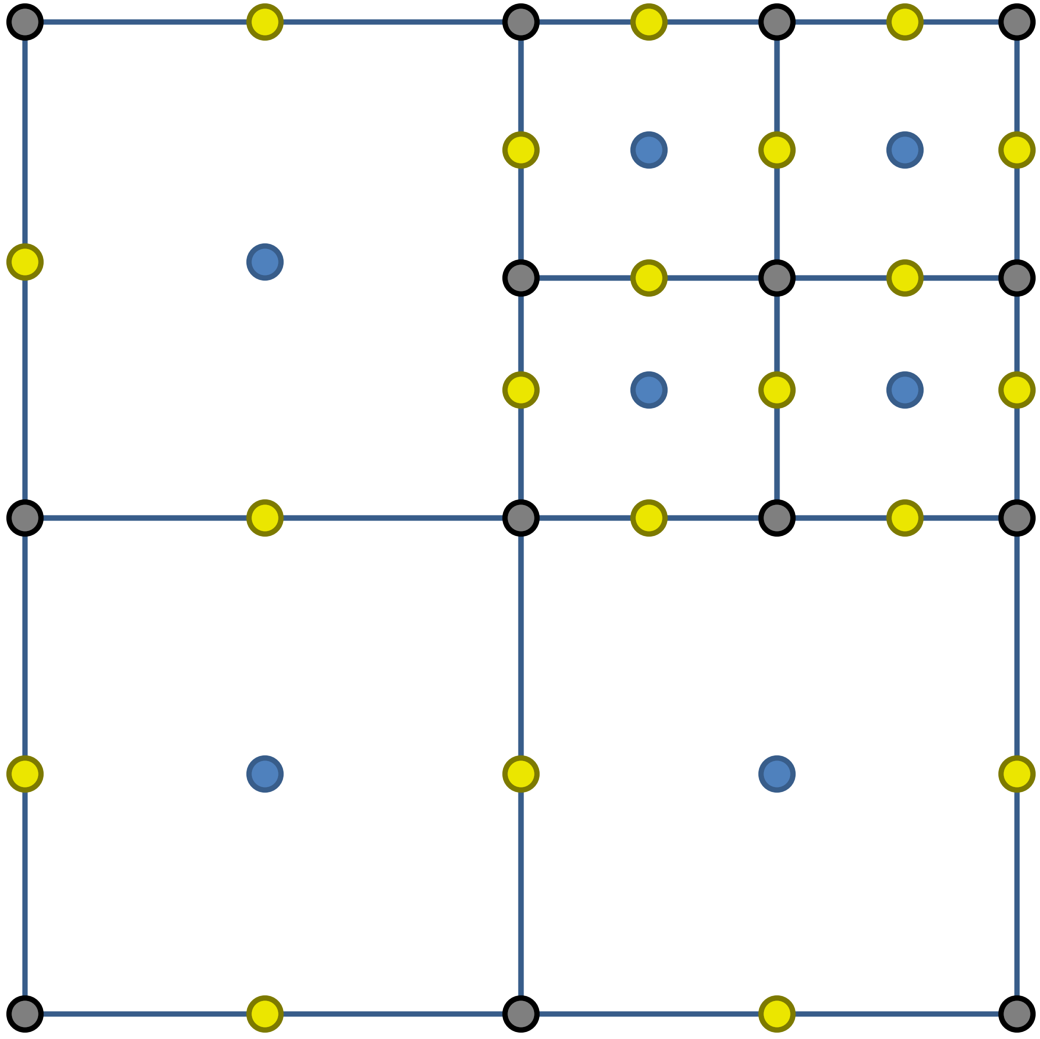


Building Simplices



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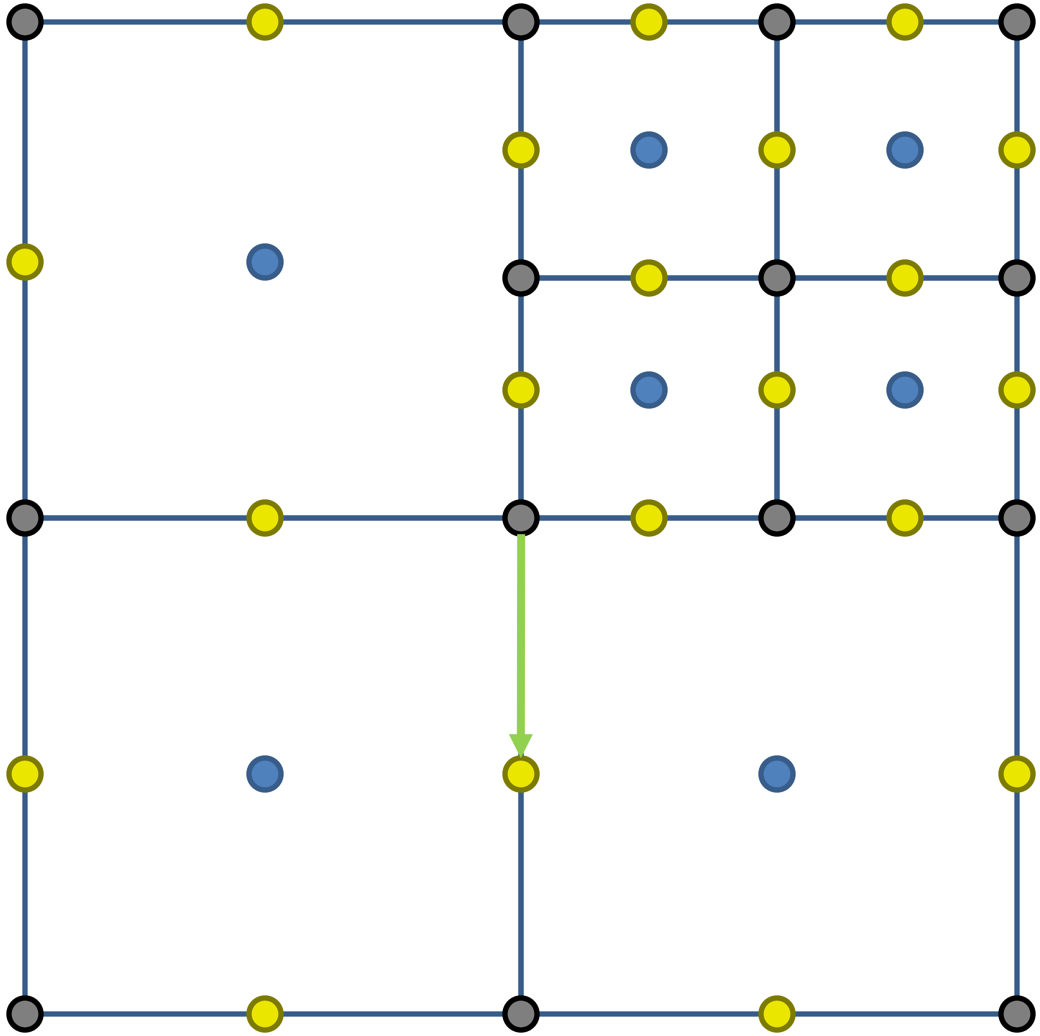

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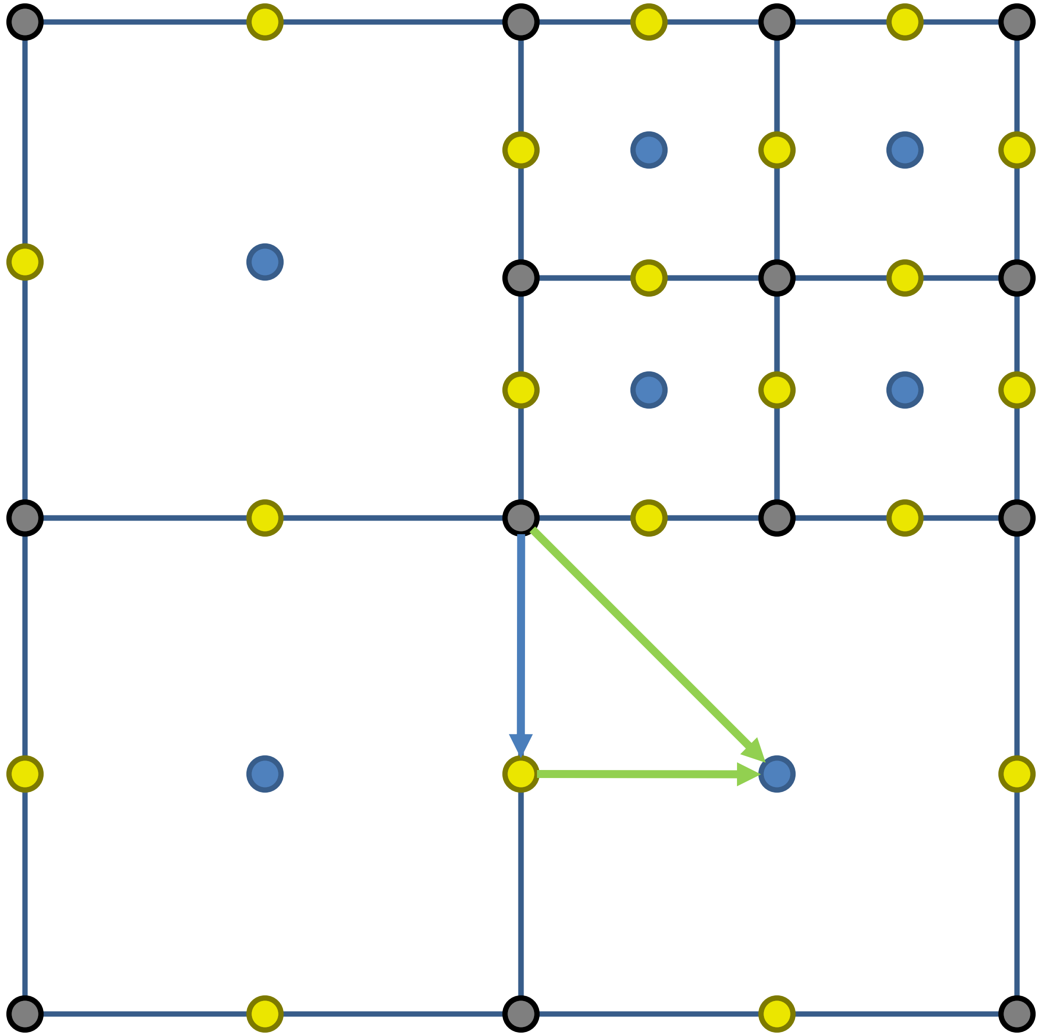

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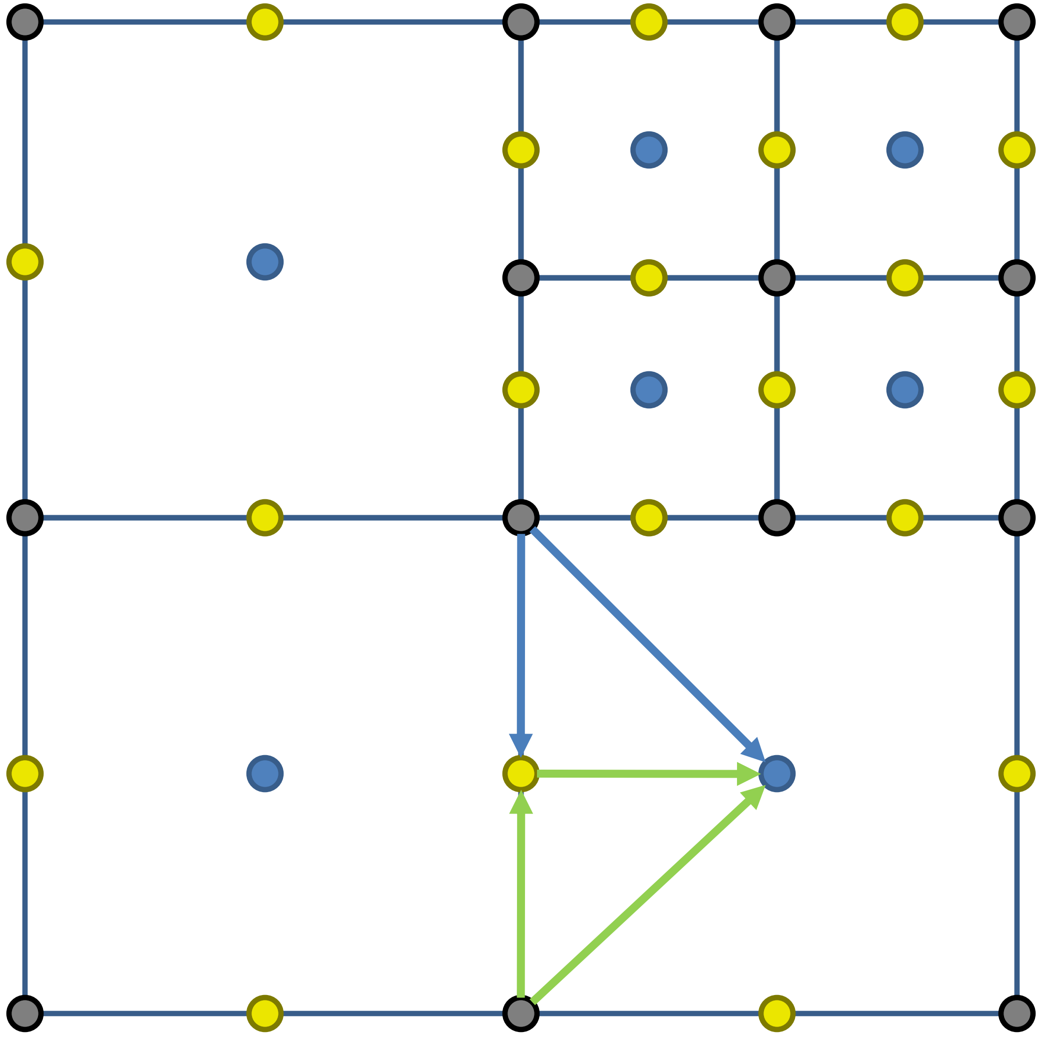

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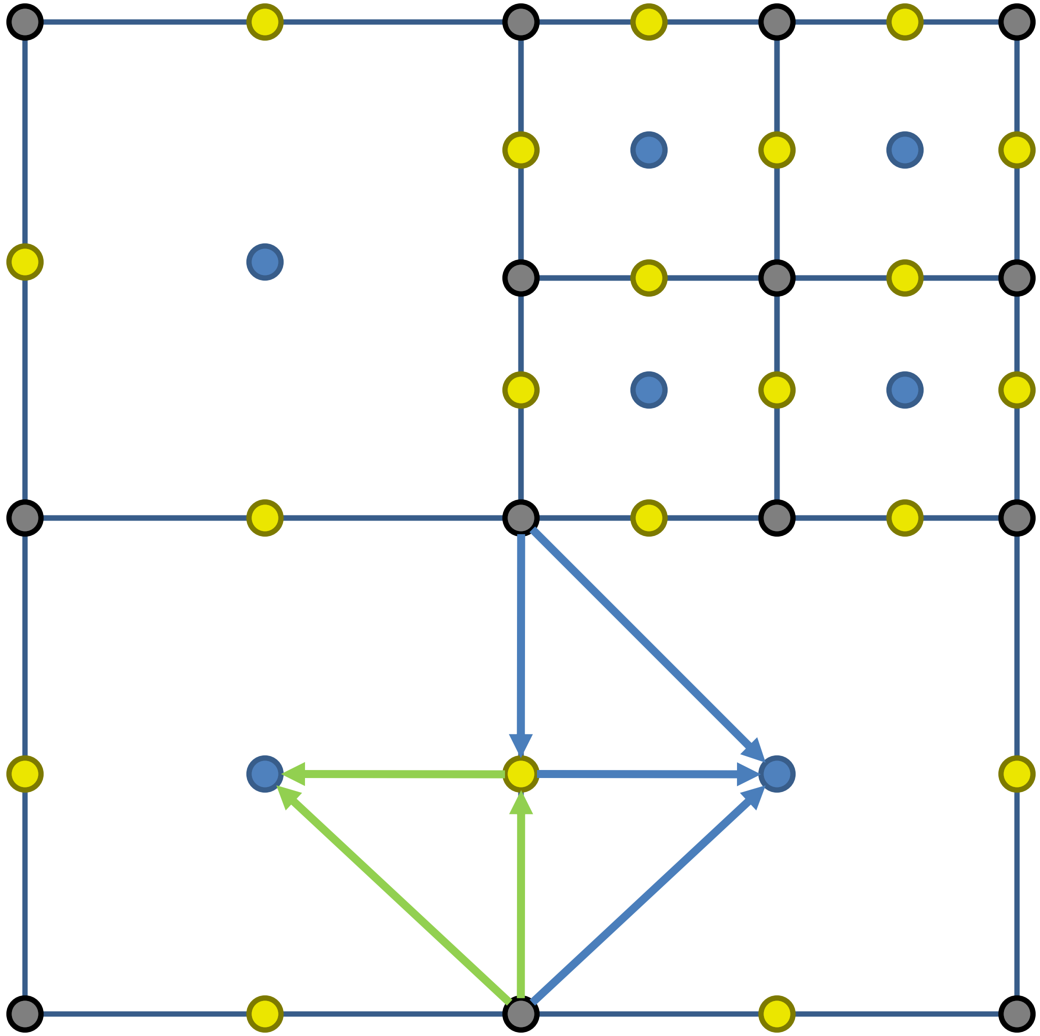

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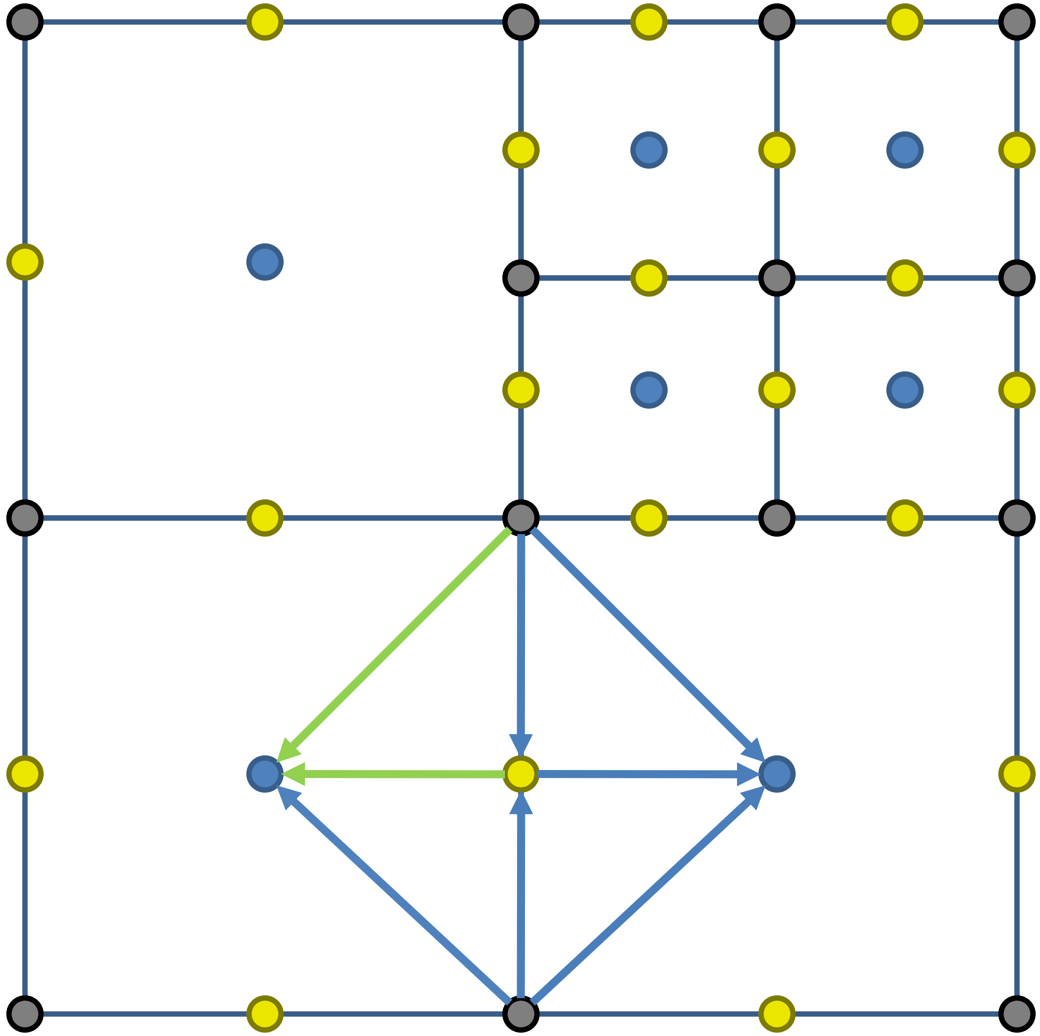

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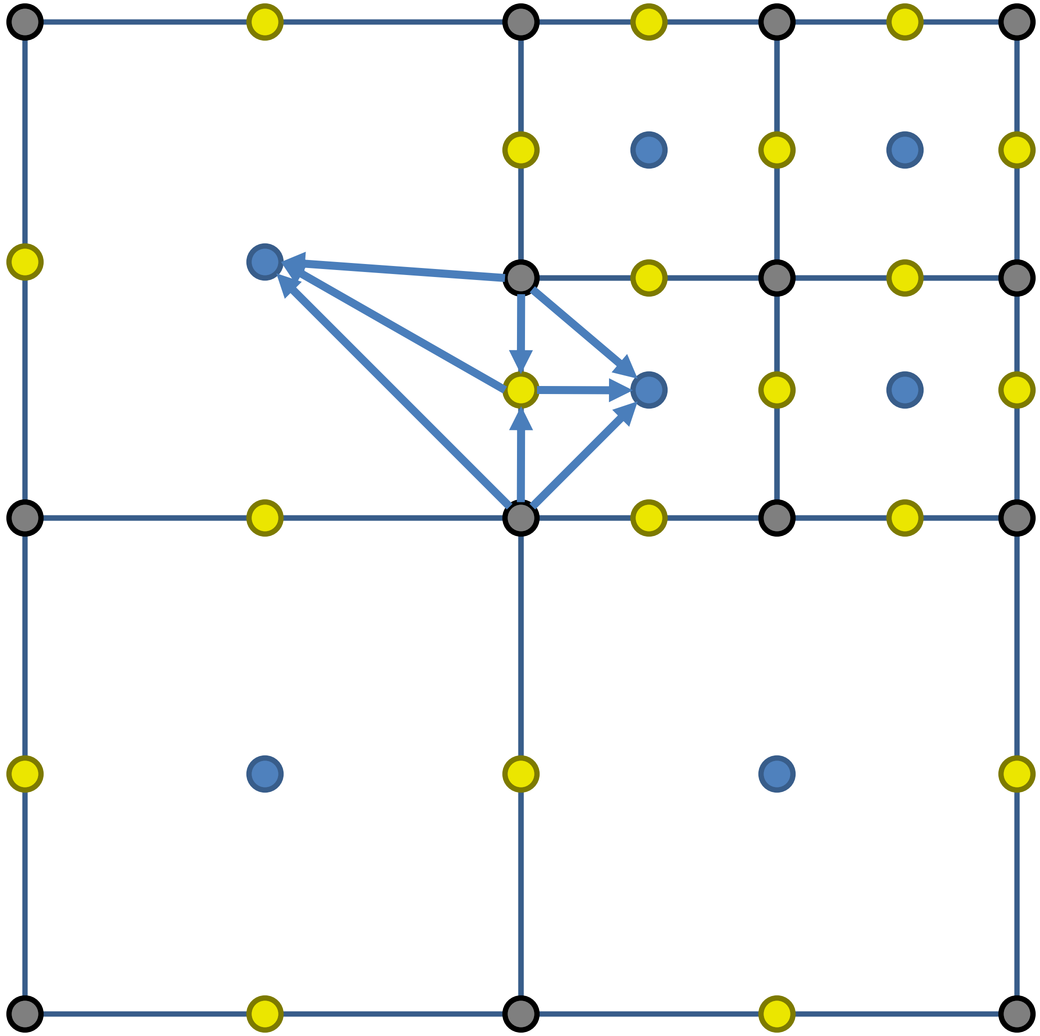

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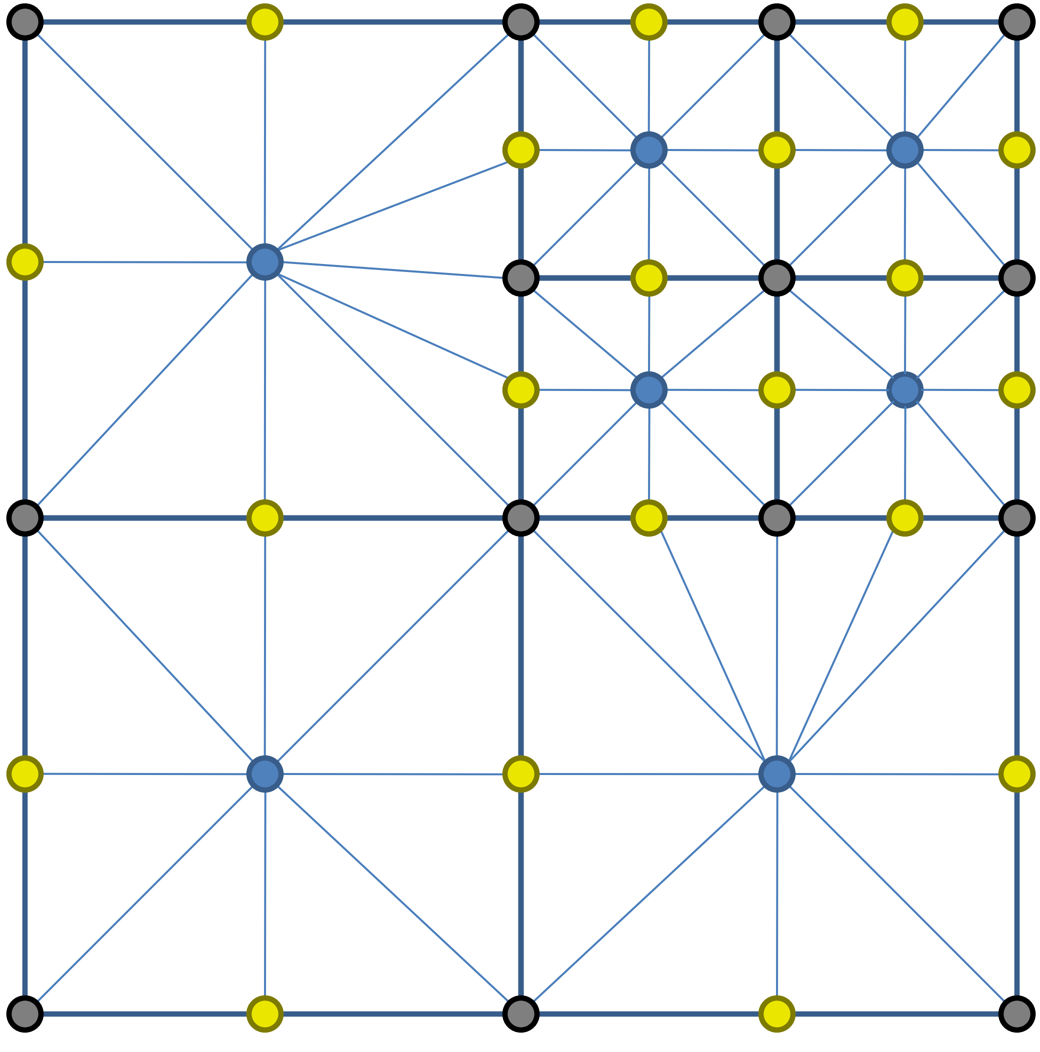
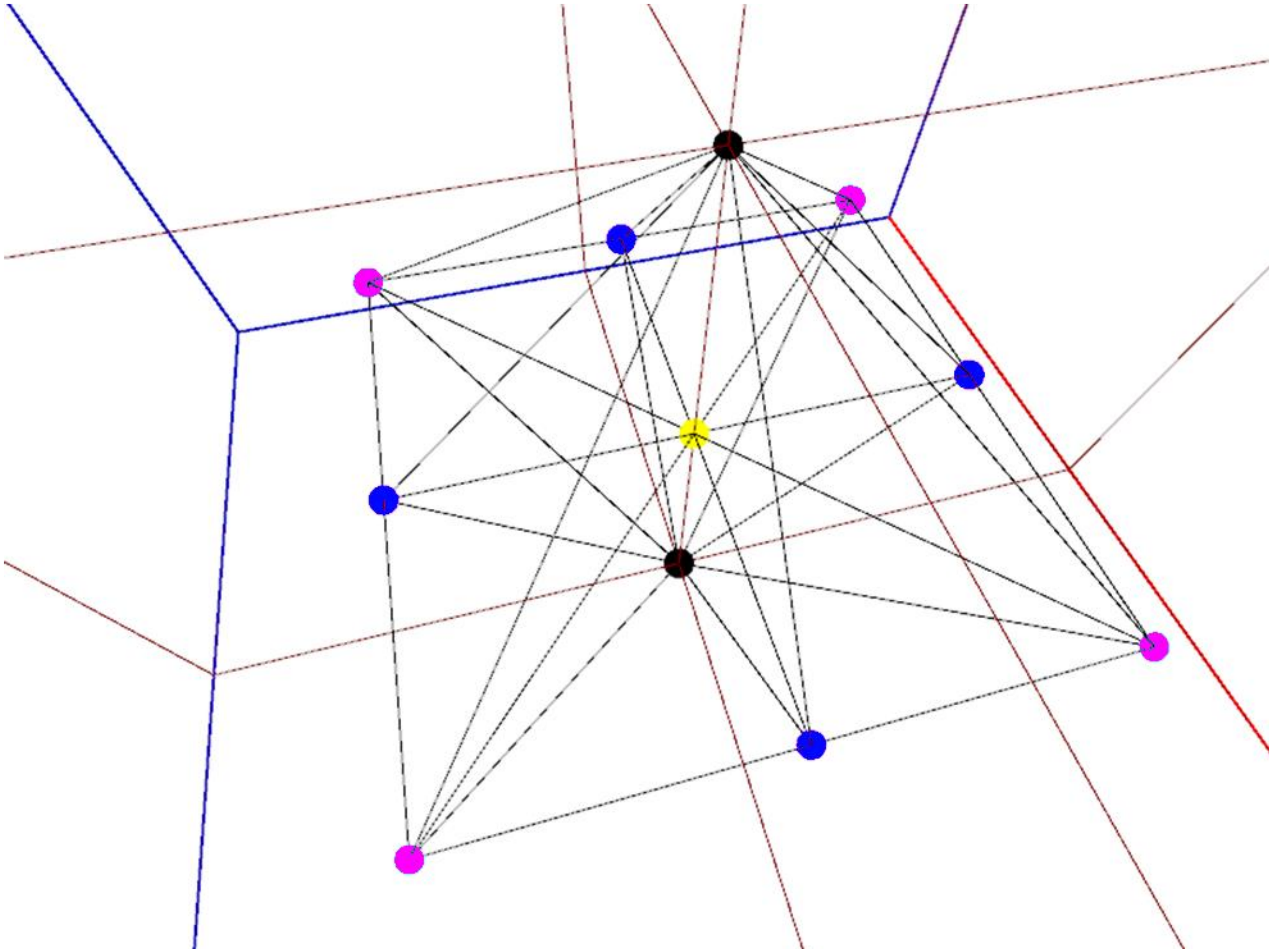


Traversing Tetrahedra



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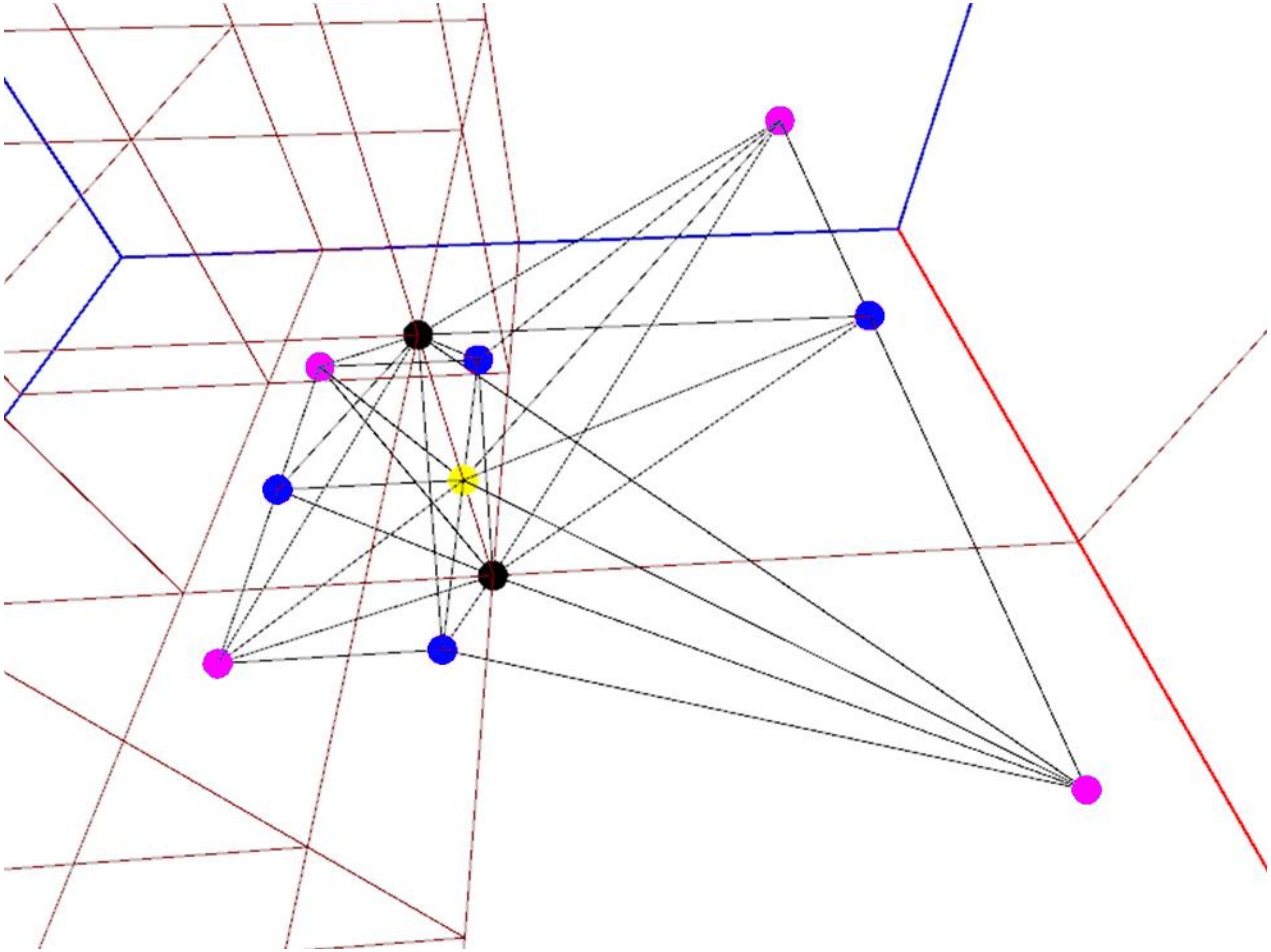

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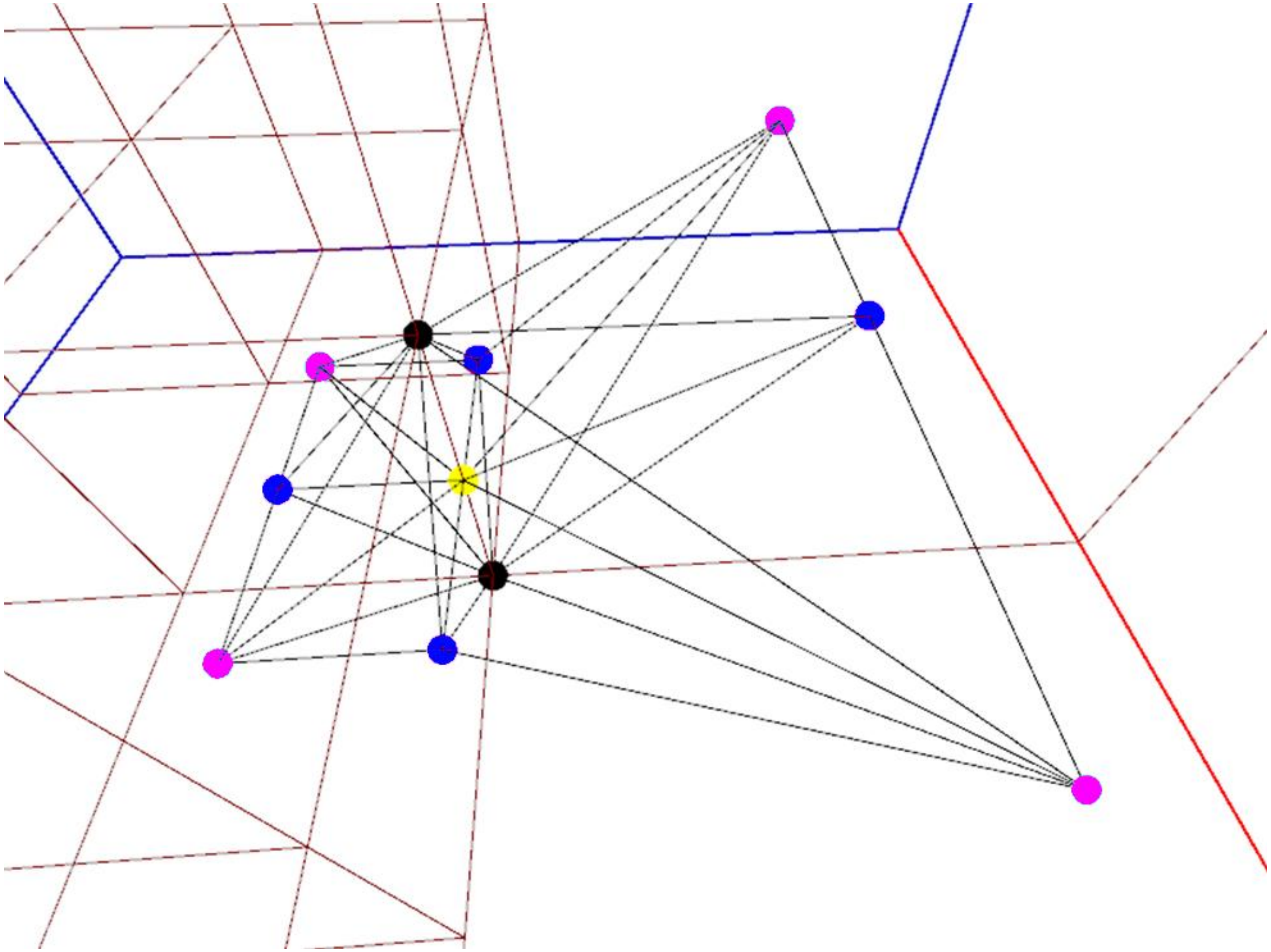


Octree Traversal from DC [Ju et al. 2002]

Finding Features

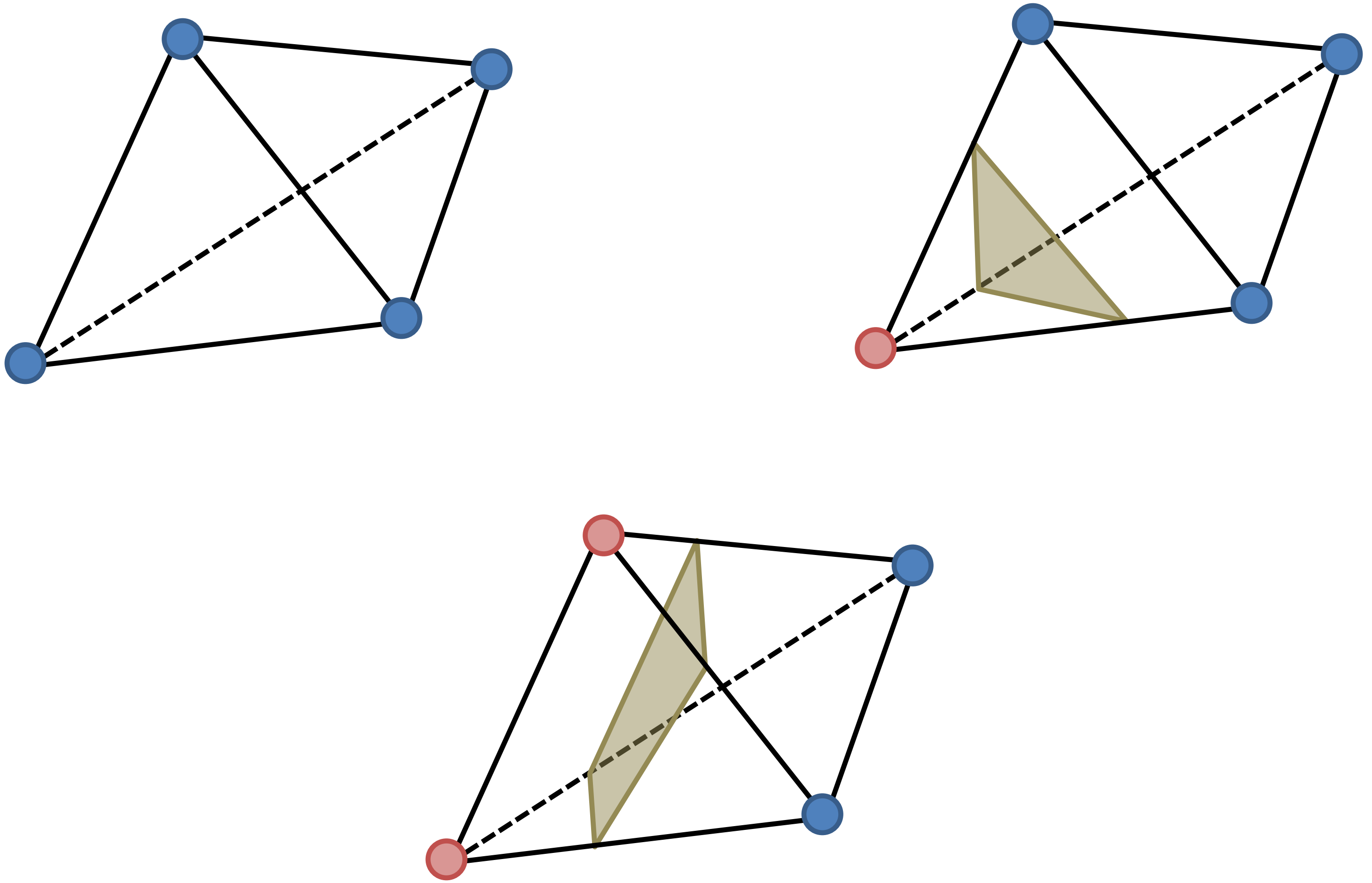
- Minimize distances to planes

$$\bar{p} = \langle p, F(p) \rangle$$

$$\bar{n}_i = \langle \nabla F(p_i), -1 \rangle$$

$$\min_{x} \sum_{i} (\bar{n}_i \cdot \bar{x} - \bar{n}_i \cdot \bar{p}_i)^2$$

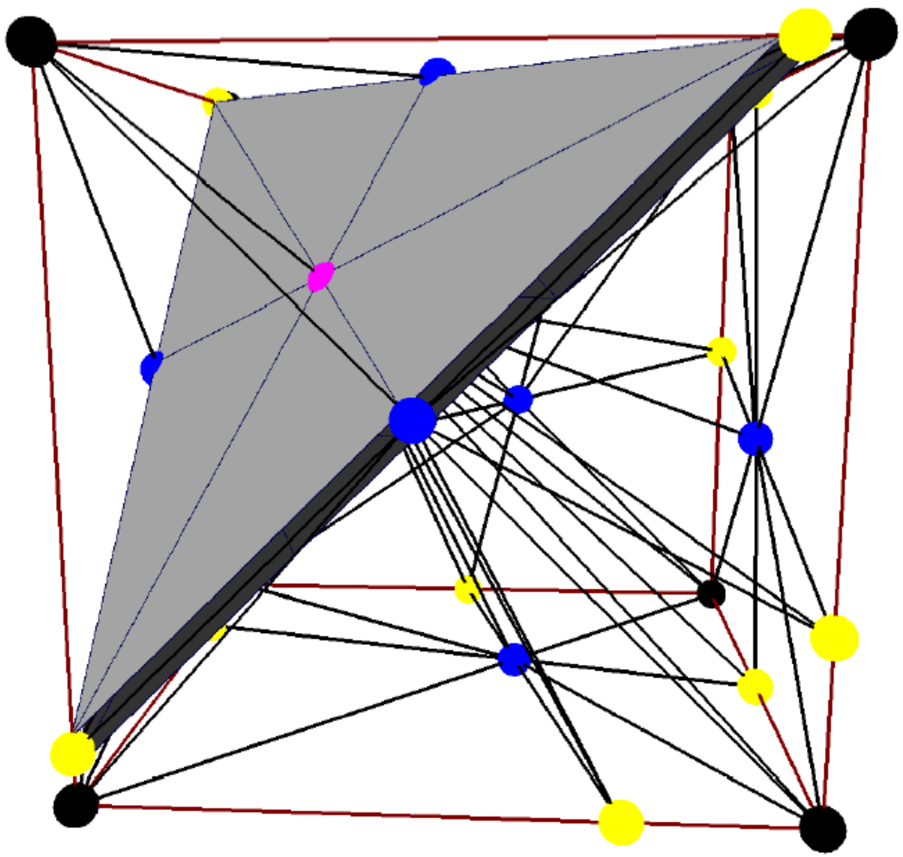
Surfaces from Tetrahedra



Manifold Property

- Vertices are constrained to their dual m-cells
- Simplices are guaranteed to not fold back
- Tetrahedra share faces
- Freedom to move allows reproducing features

Finding Features



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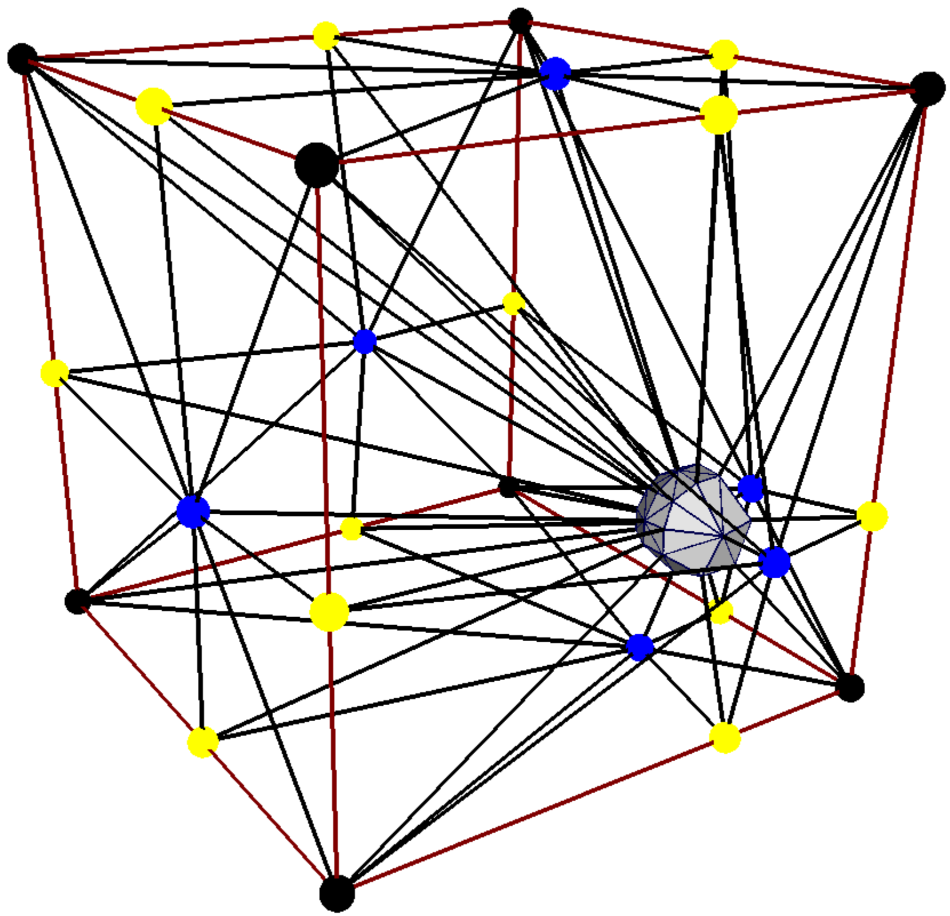

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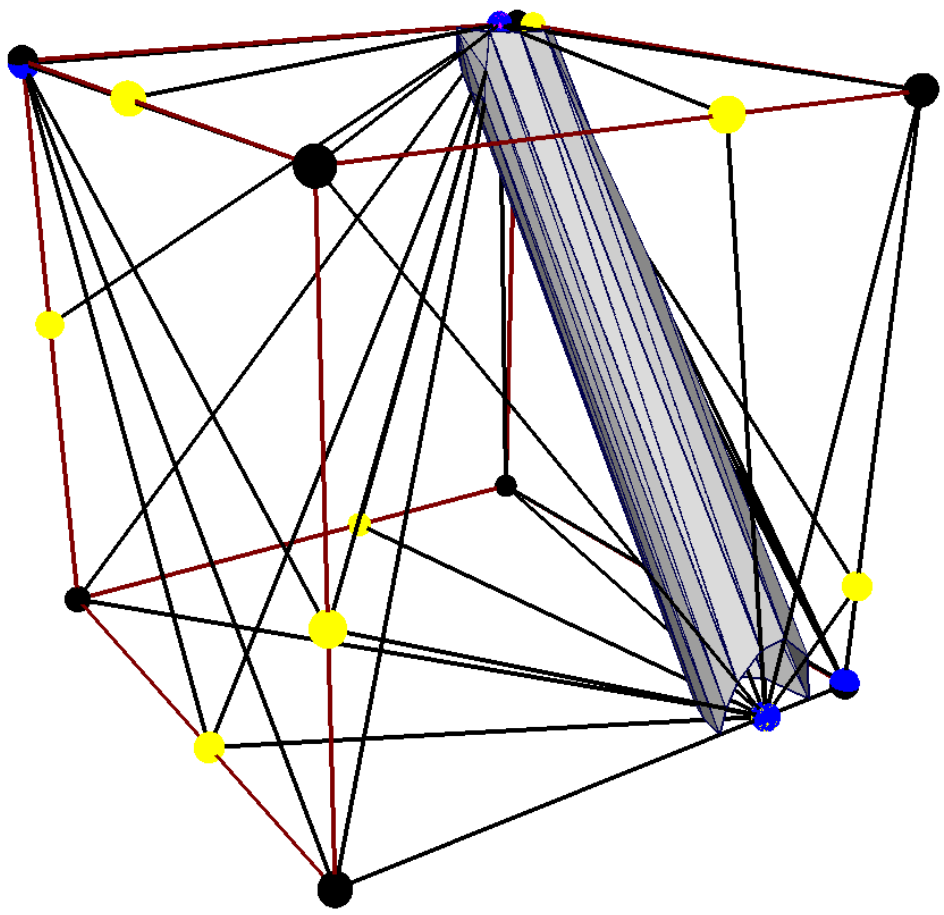

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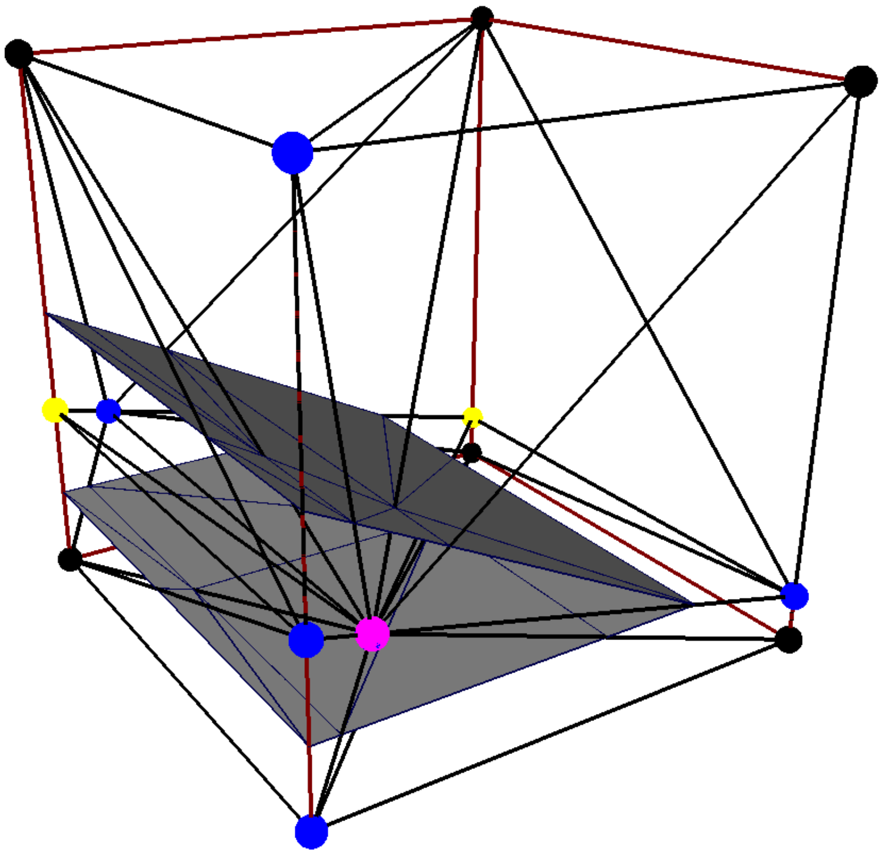
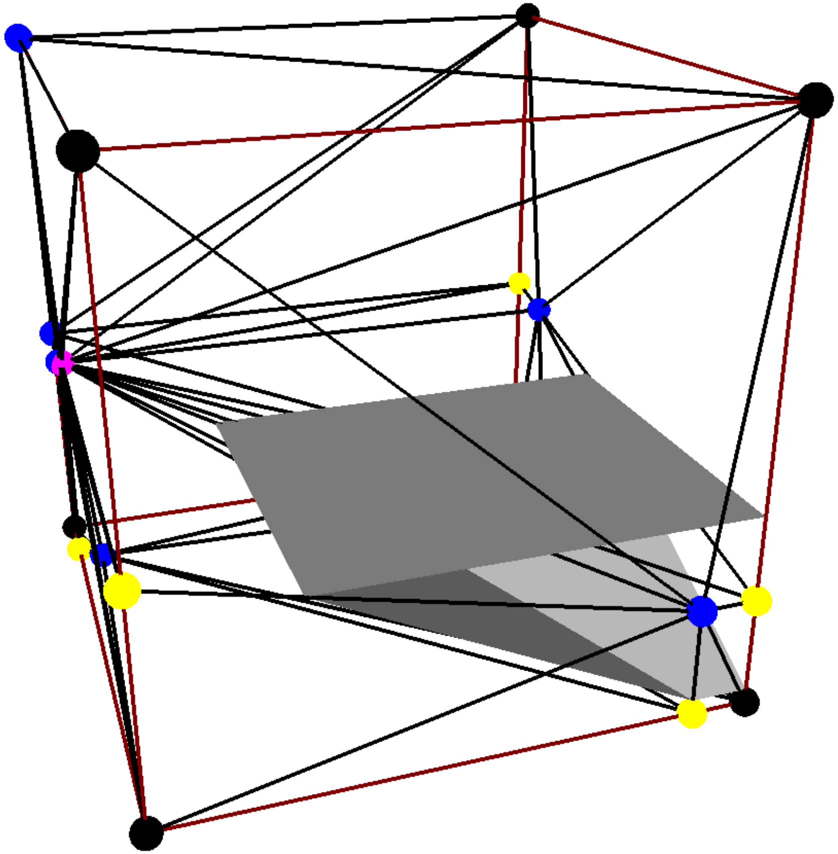
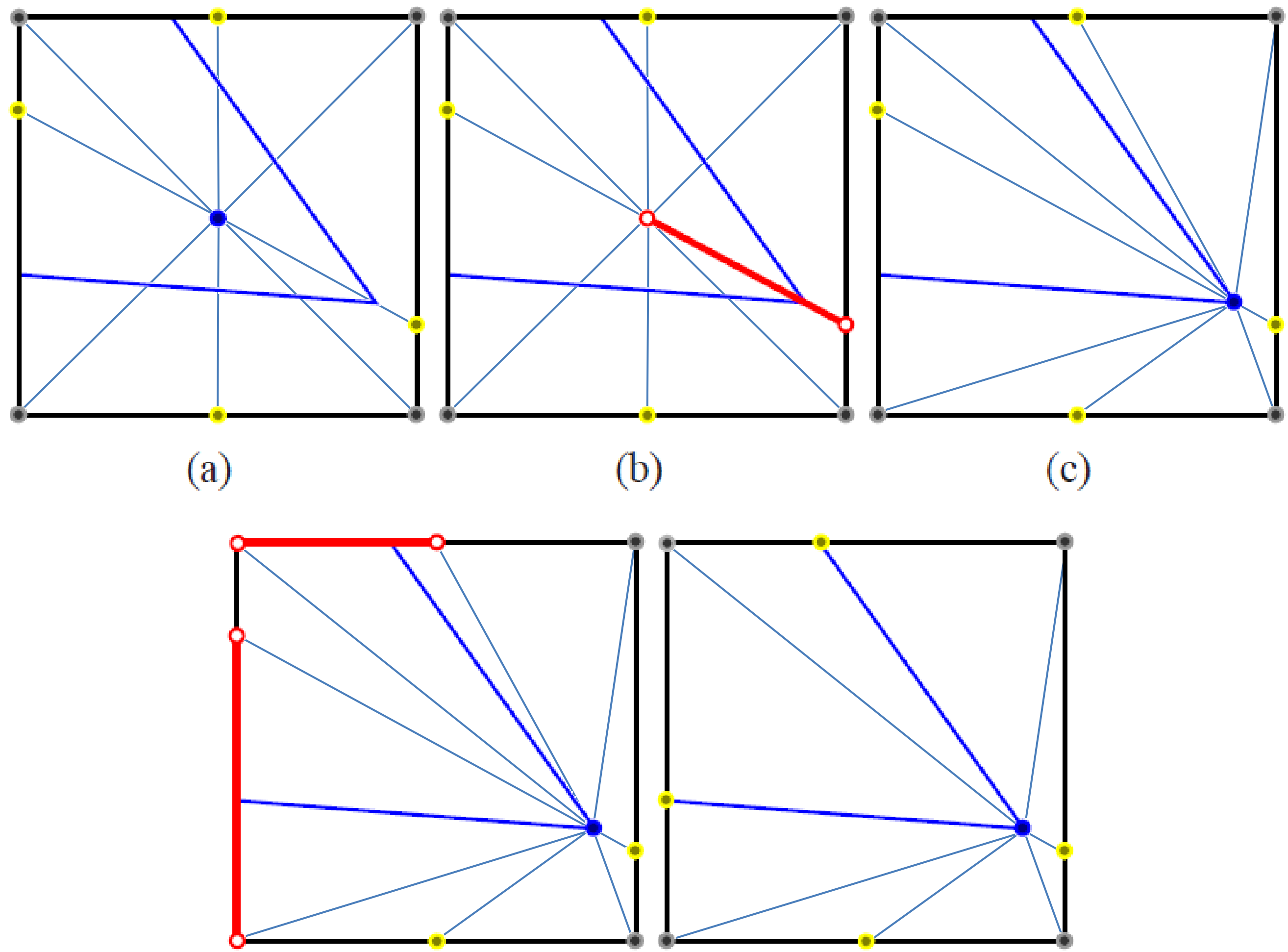


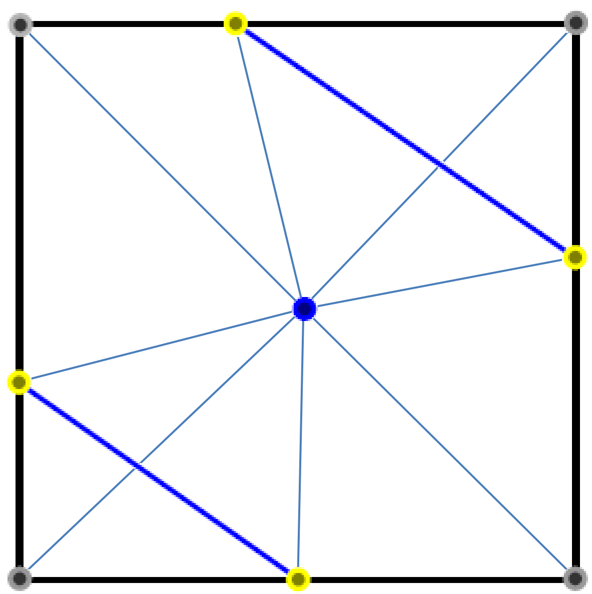


Improving Triangulation

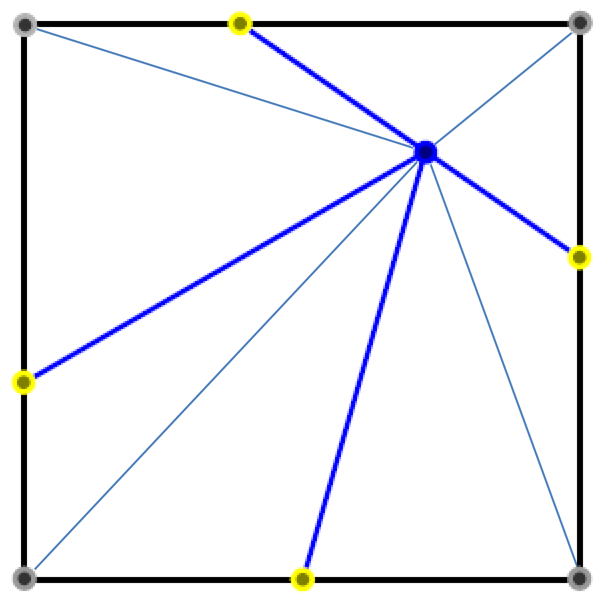


(a) (b) (c) (d) (e)

Possible Problem: Face

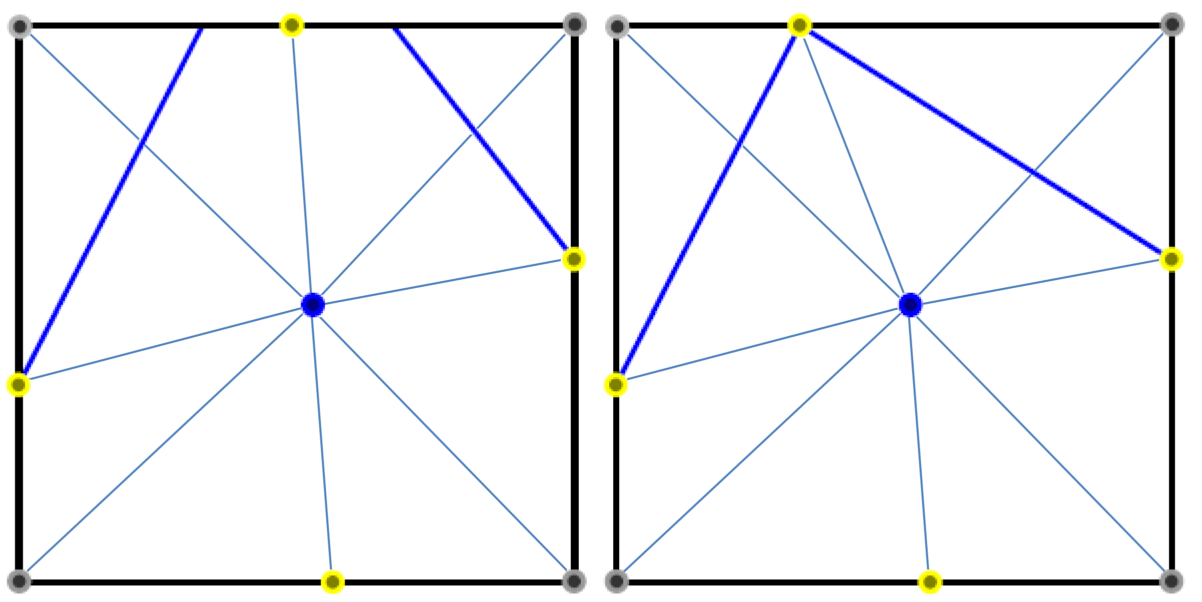


Before



After

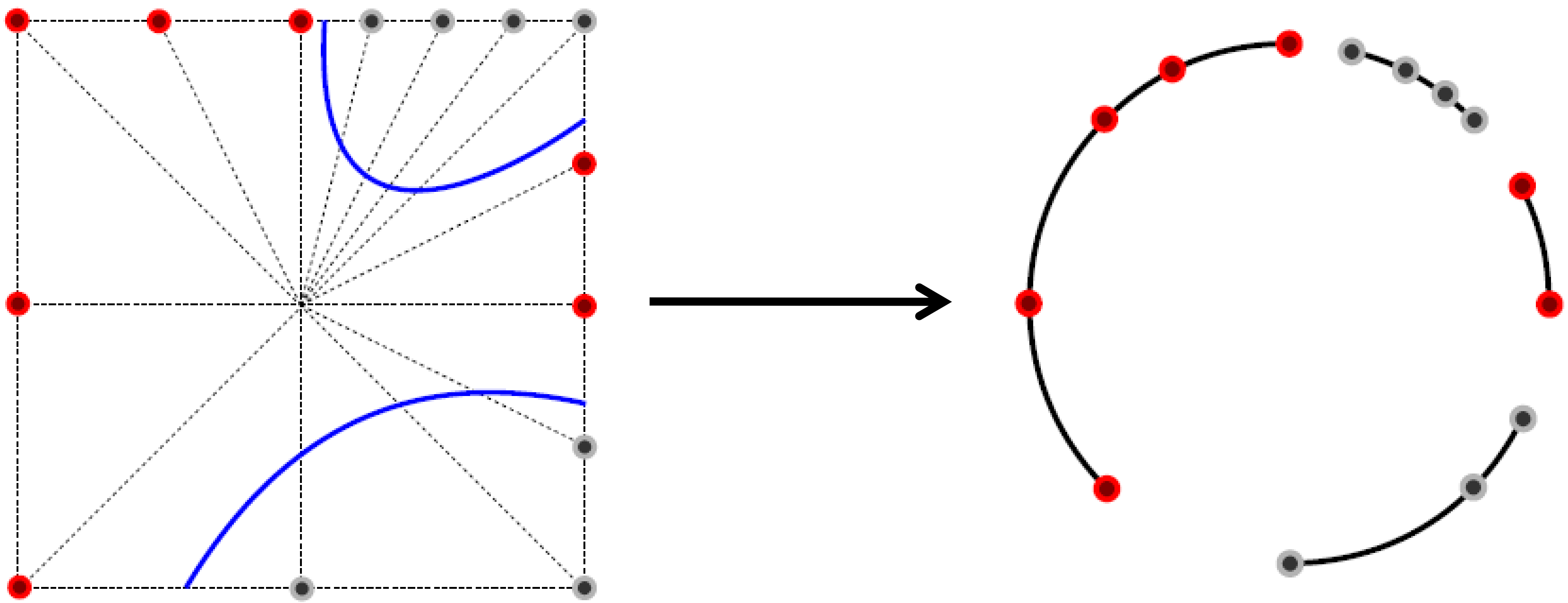
Possible Problem: Edge



Before After

Preserving Topology

- Only move vertex to surface if there is a single contour.
- Count connected components.



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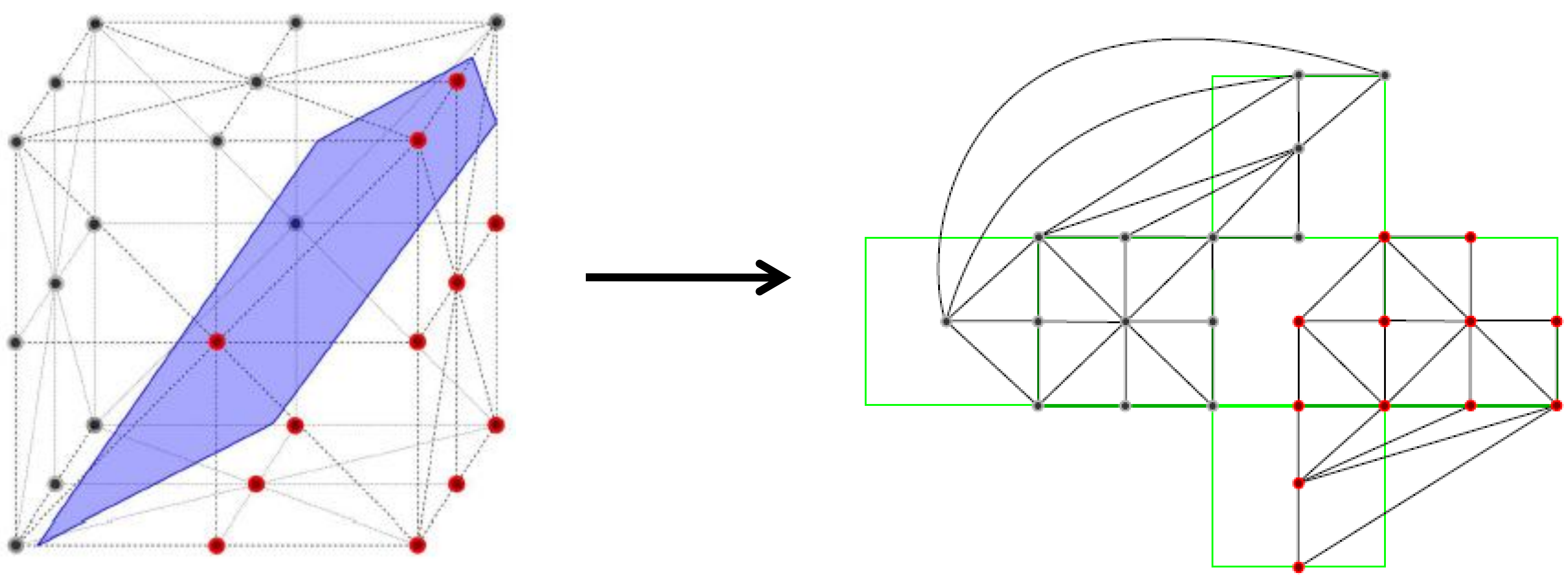

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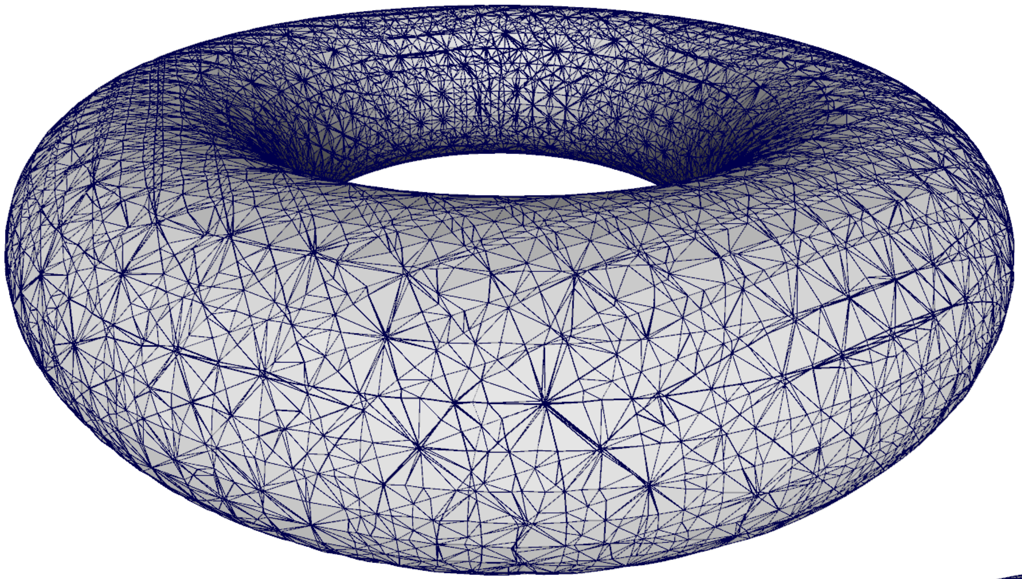
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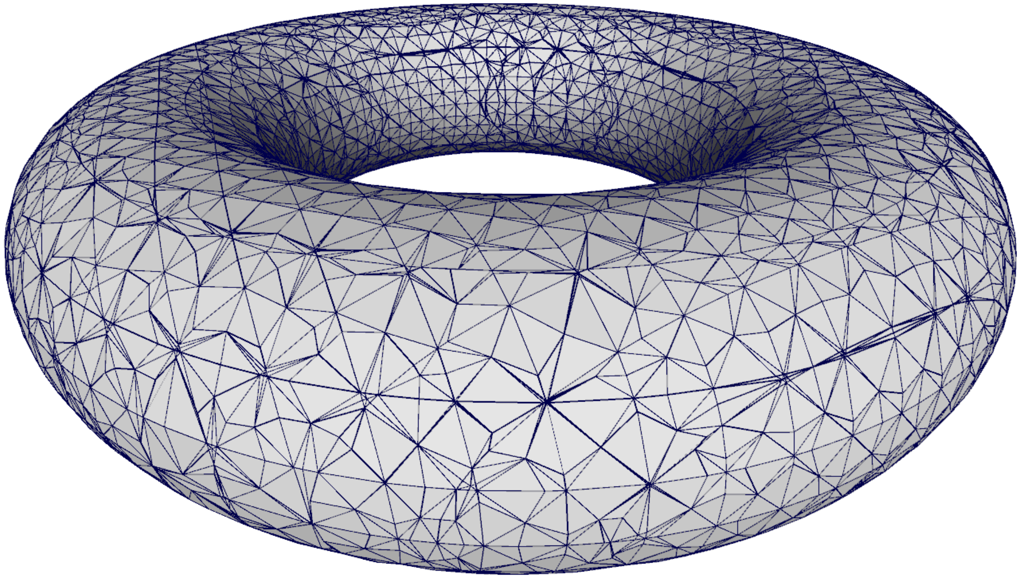
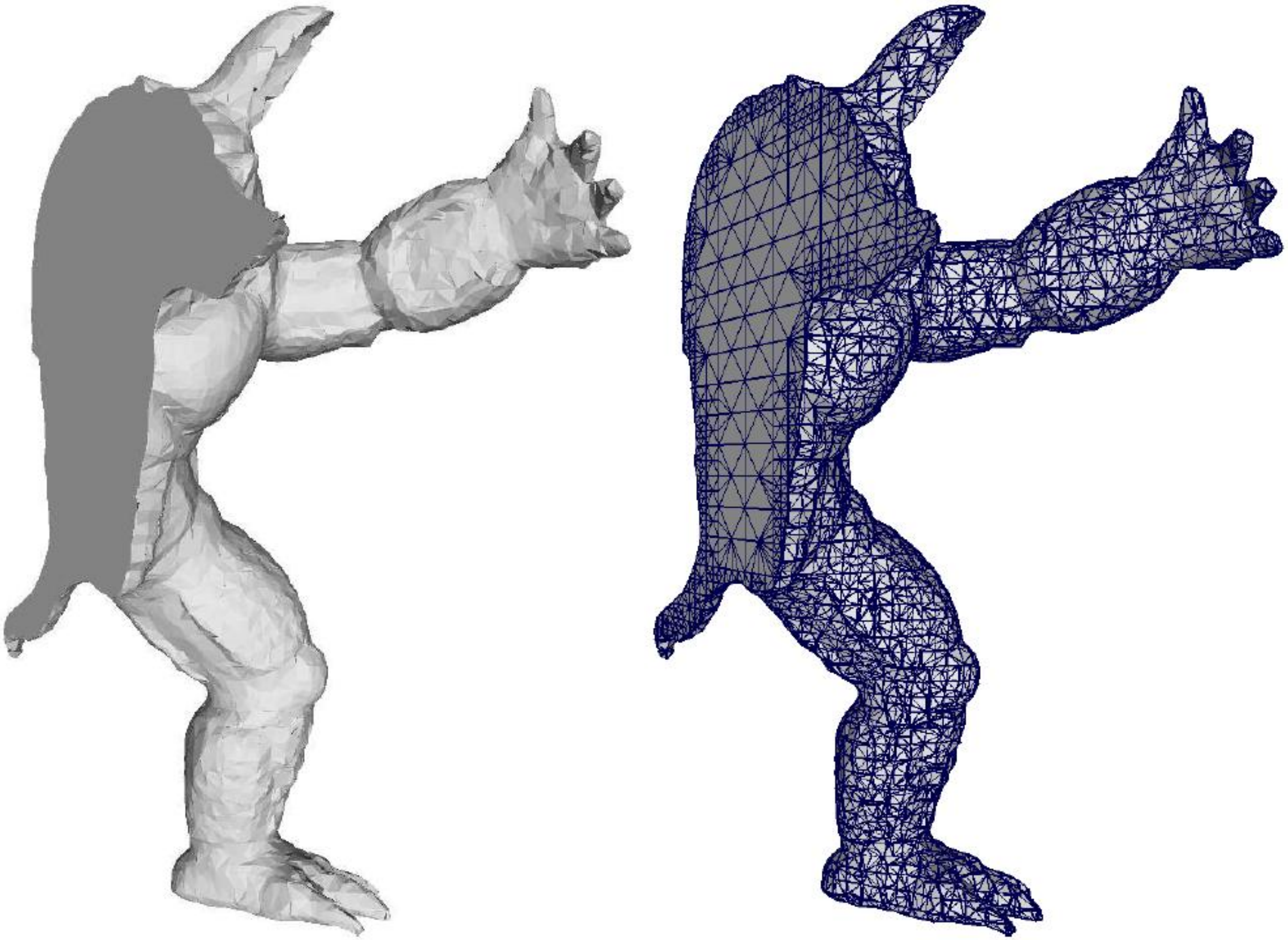

After

Results



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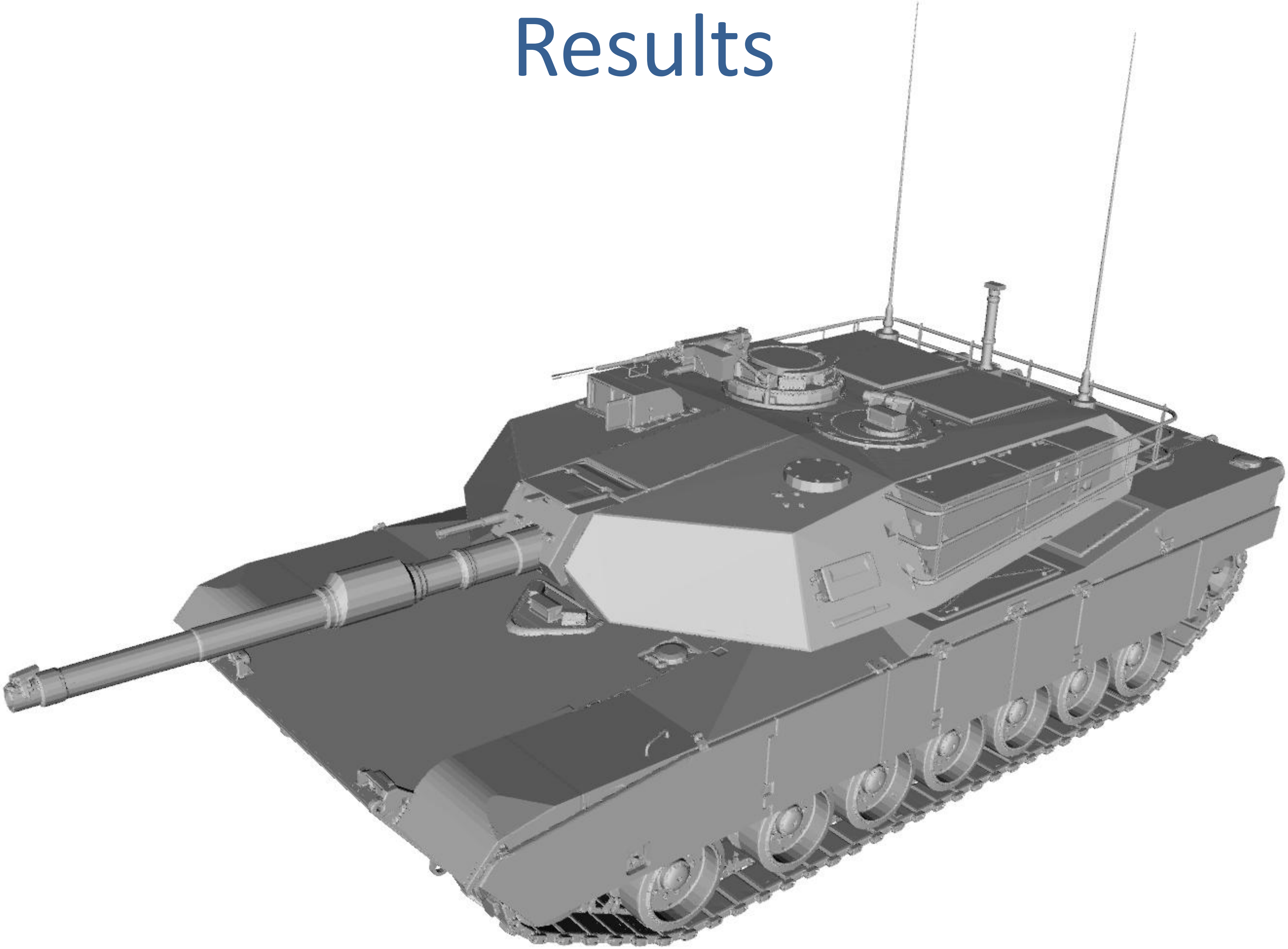
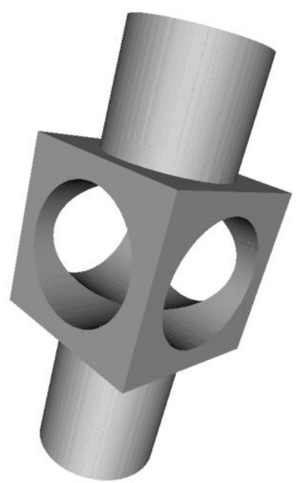
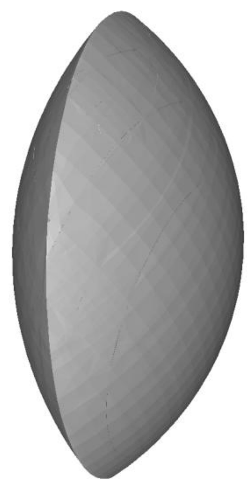
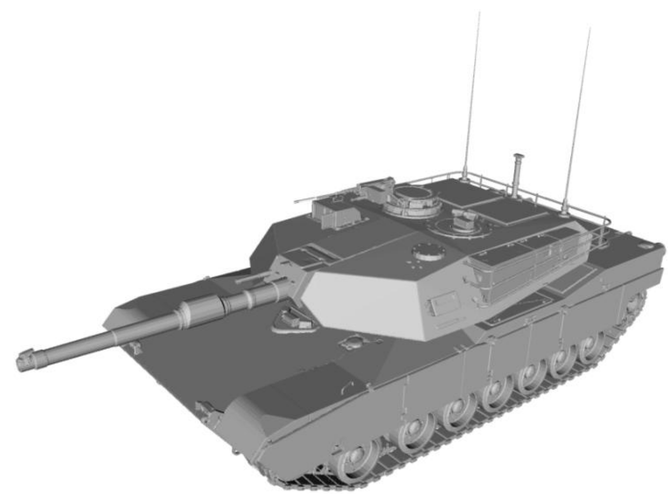


Times

	Armadillo Man	Mechanical Part	Lens	Tank
Depth	8	9	10	8
Ours	2.58s	4.81s	9.72s	8.78s
Ours (Improved Triangles)	2.69s	6.80s	10.35s	8.19s
Dual Marching Cubes	1.85s	3.54s	6.42s	5.29s
Dual Contouring	1.35s	2.97s	5.99s	3.78s

Conclusions

- Calculate isosurfaces over piecewise smooth functions
- Guarantee manifold surfaces
- Reproduce sharp and thin features
- Improved triangulation