SAND2015-8779C

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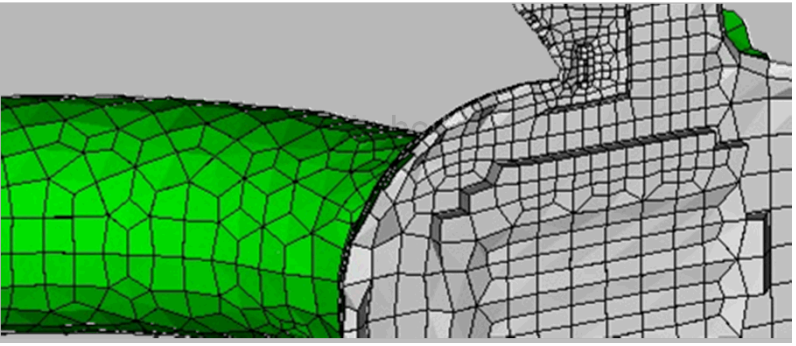
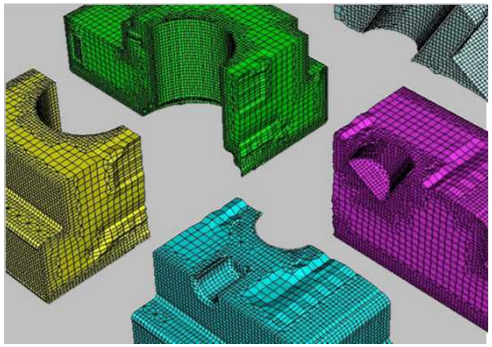
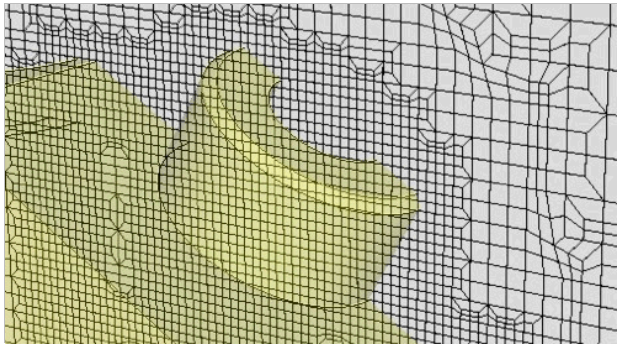

A Template-Based Approach for Parallel Hexahedral Two-Refinement

Steven J. Owen, Ryan M. Shih

24th International Meshing Roundtable
October 12-14, 2015
Austin, Texas

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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Hex Meshing

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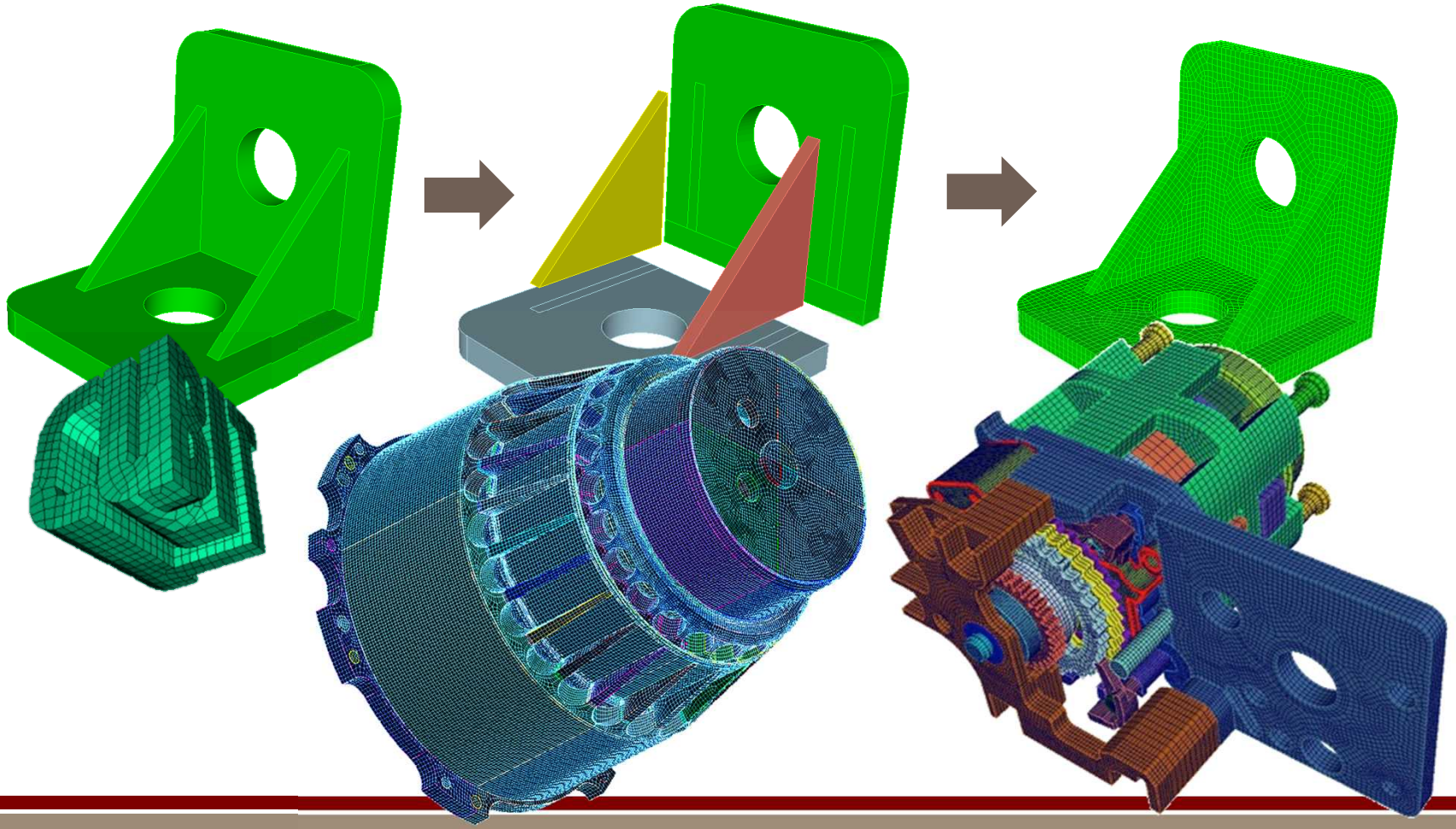

Hex Meshing for Next Generation Platforms

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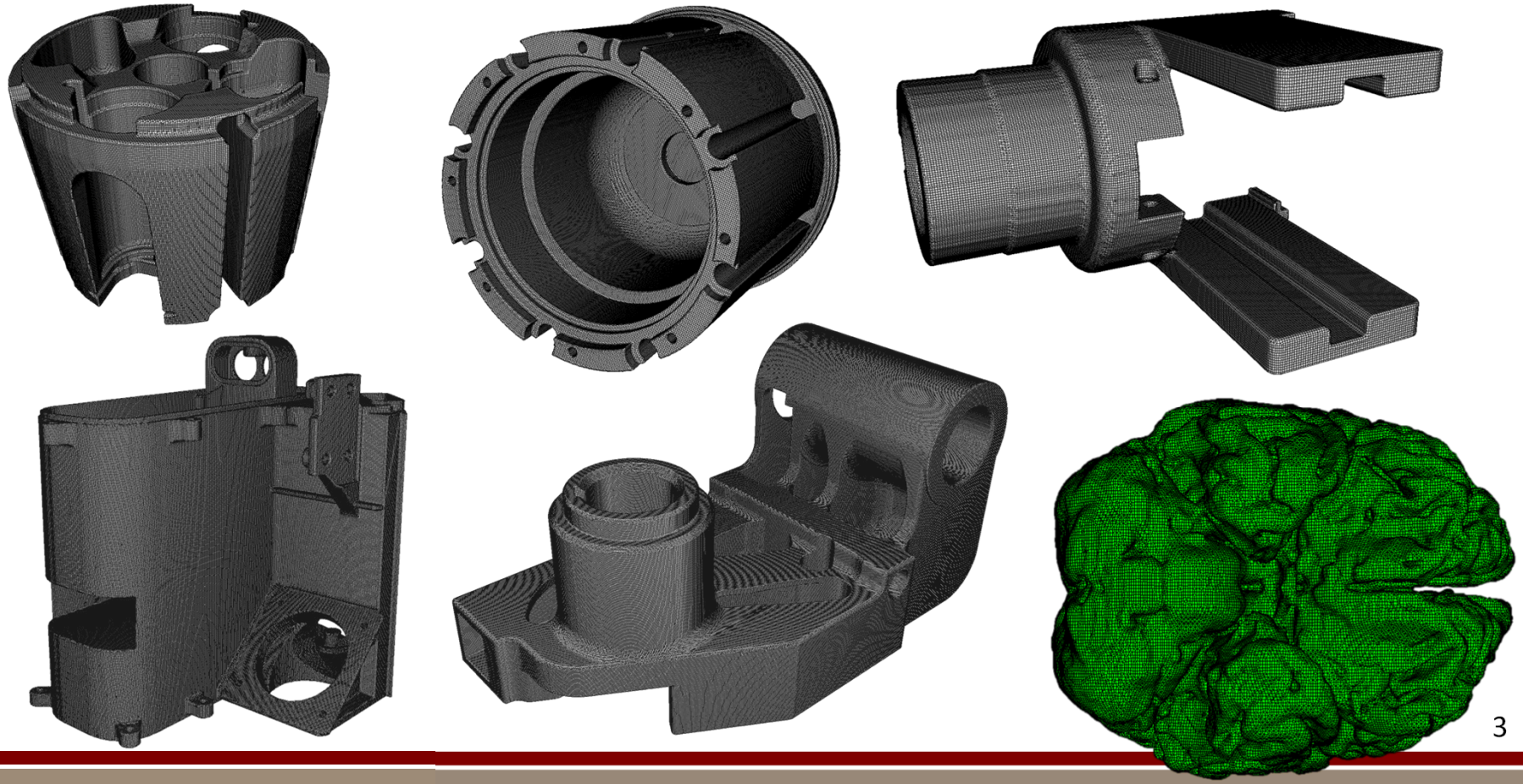

Adaptive Overlay Grid

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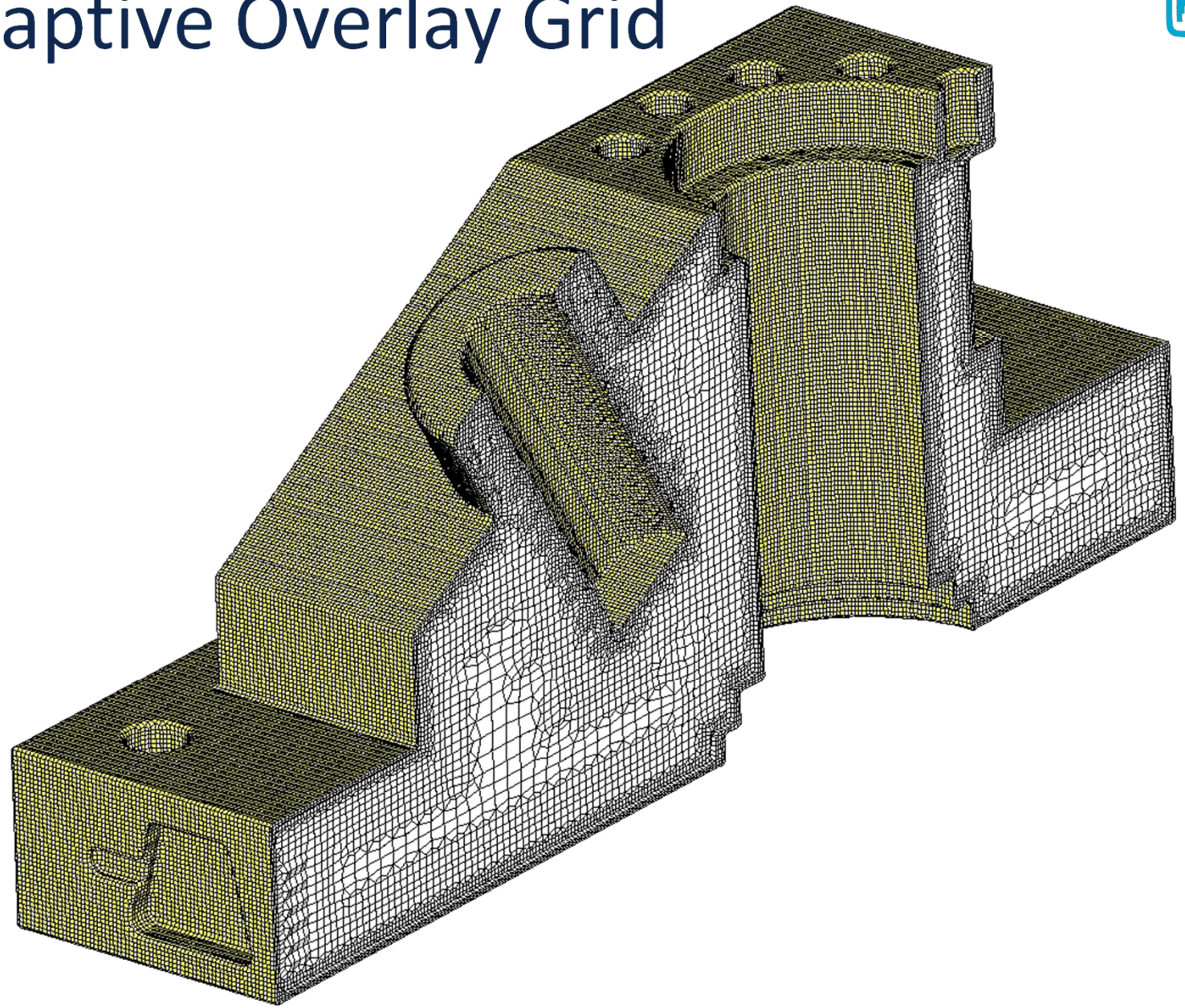
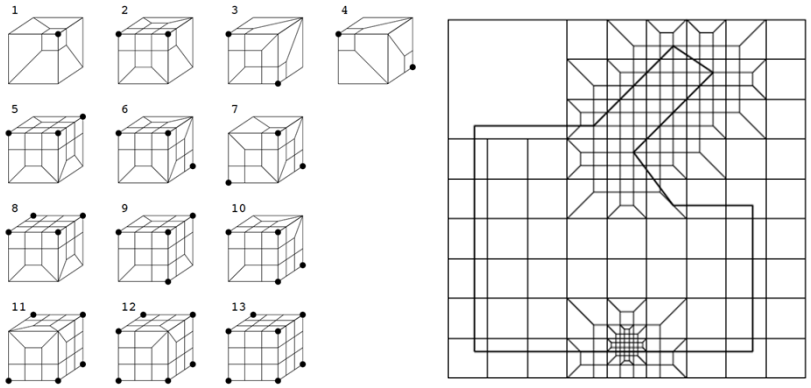
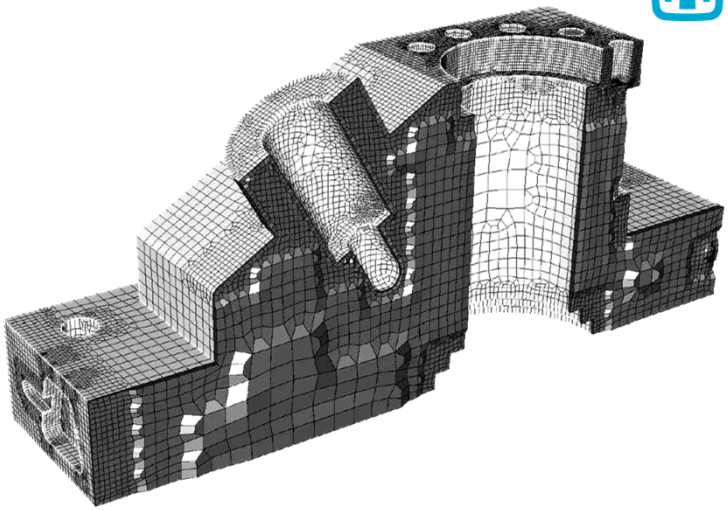


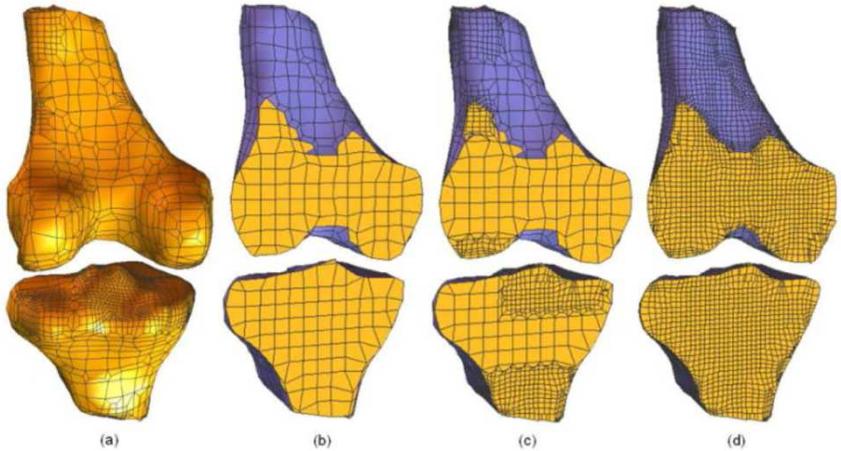
Background



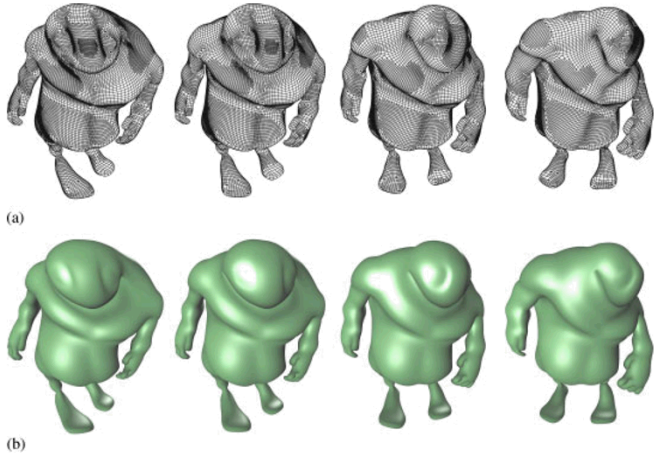
Robert Schneiders, Algorithms for quadrilateral and hexahedral mesh generation. In: Proceedings of the VKI lecture series on computational fluid dynamics (2000)



Loic Marechal, Advances in Octree-Based All-Hexahedral Mesh Generation: Handling Sharp Features, Proceedings of the 18th International Meshing Roundtable pp. 65-84



Yongjie Zhang and Chandrajit Bajaj , Adaptive and Quality Quadrilateral/Hexahedral Meshing from Volumetric Data Comput Methods Appl Mech Eng. 2006 Feb 1; 195(9): 942–960



Mohamed S. Ebeida, Anjul Patney, John D. Owens and Eric Mestreau, Isotropic conforming refinement of quadrilateral and hexahedral meshes using two-refinement templates, Int. J. Numer. Meth. Engng 2011; 88:974–985

Sculpt

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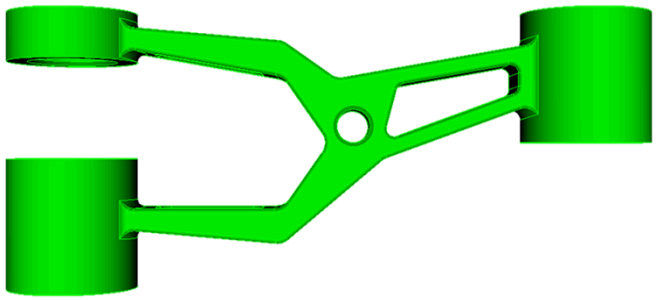
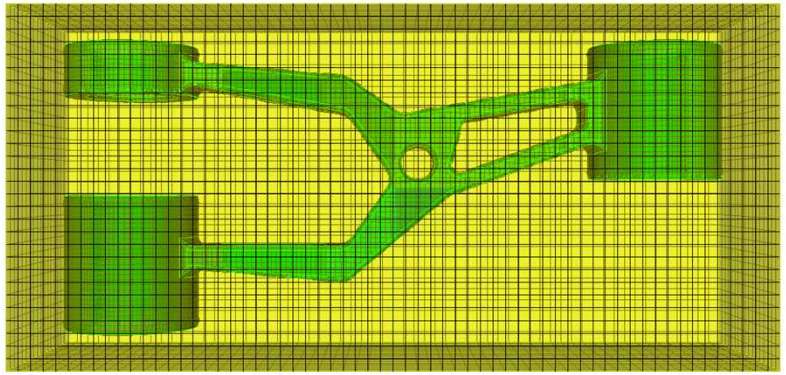
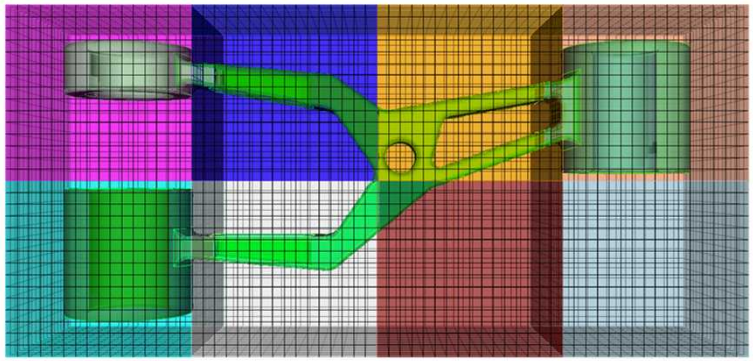


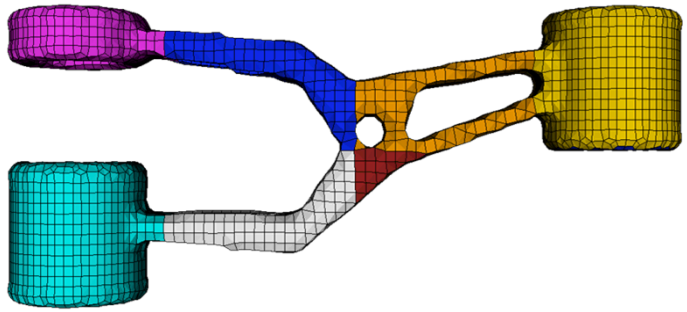
CAD geometry



Global overlay Cartesian grid

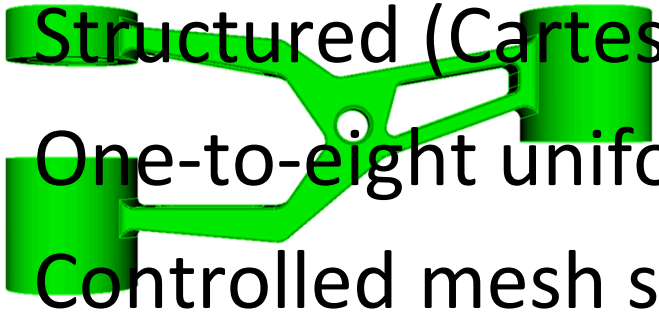


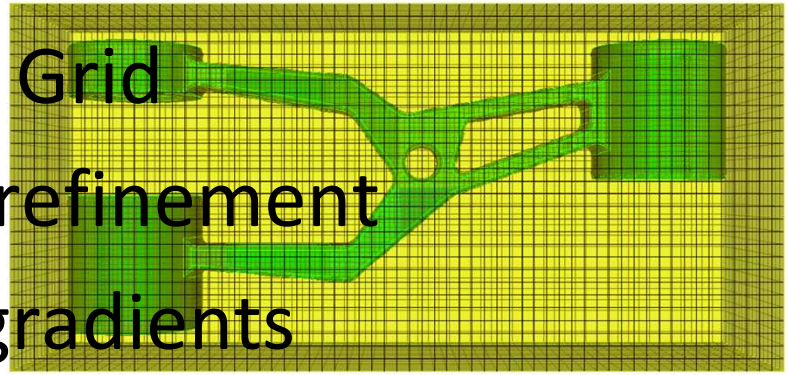
Cartesian grid decomposed and distributed amongst many processors



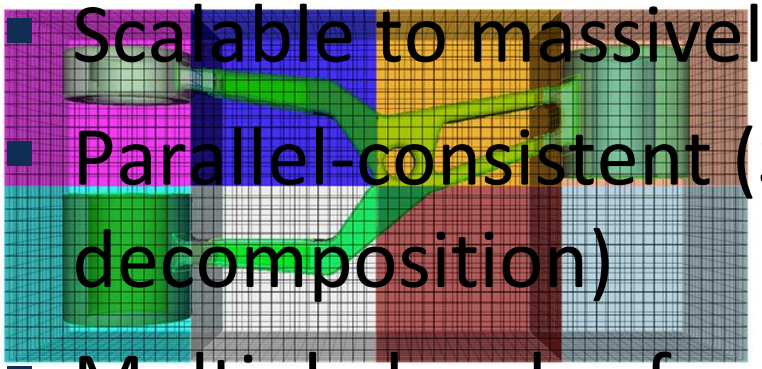
Each processor independently meshes its portion of Cartesian grid

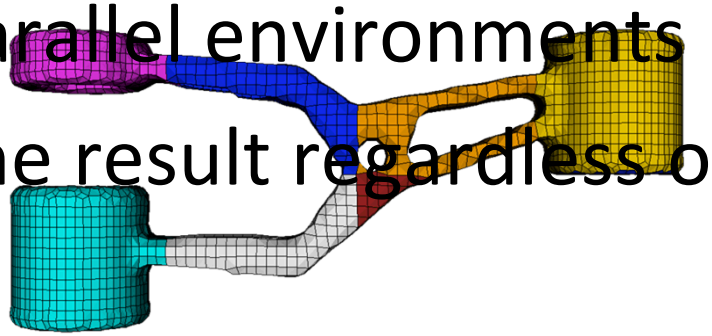
Refinement Requirements





- Structured (Cartesian) Grid
- One-to-eight uniform refinement
- Controlled mesh size gradients
- Computable Quality
- Scalable to massively parallel environments
- Parallel-consistent (Same result regardless of decomposition)

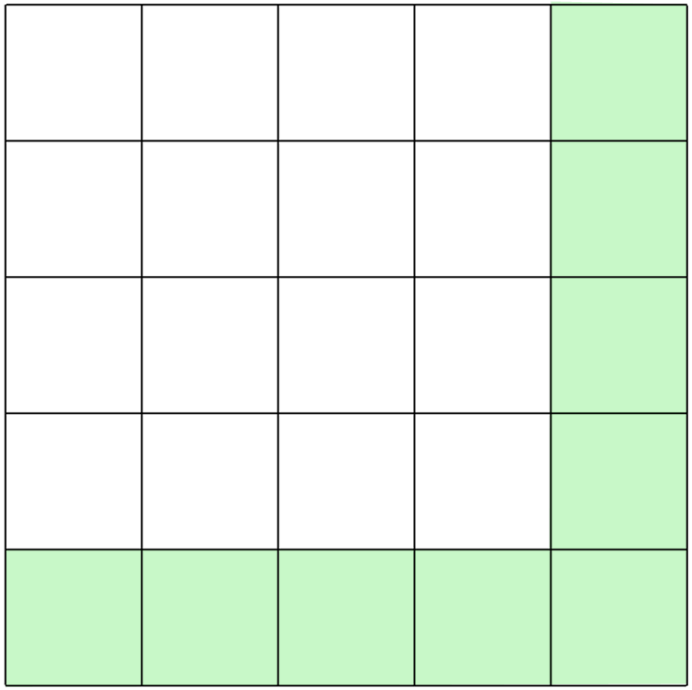




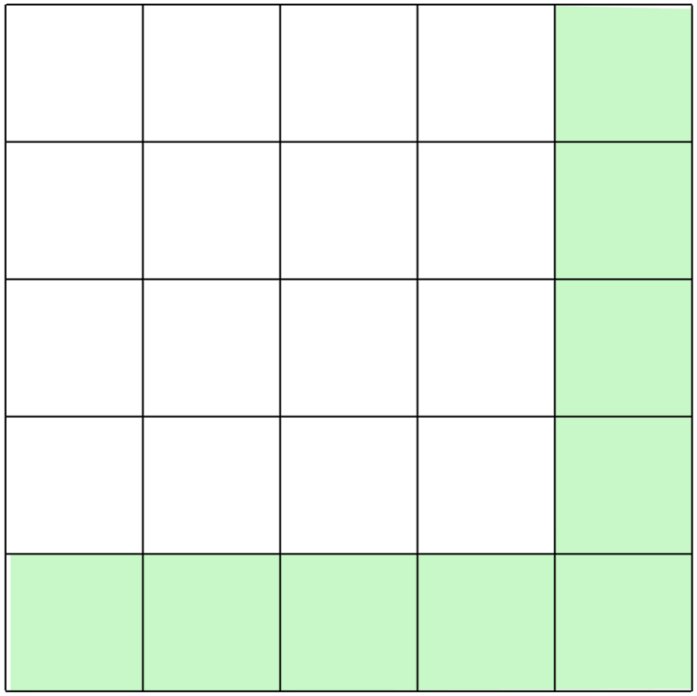
- Multiple levels of refinement

Hex Refinement

3-Refinement

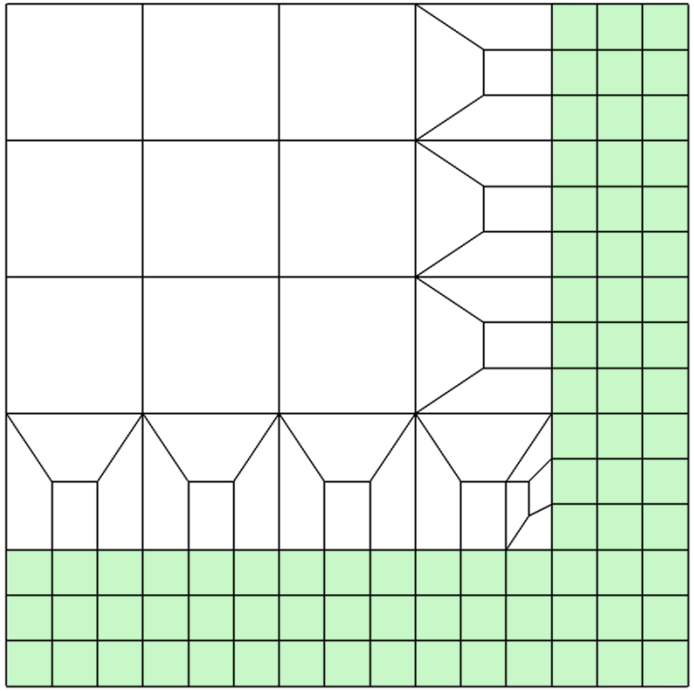


2-Refinement

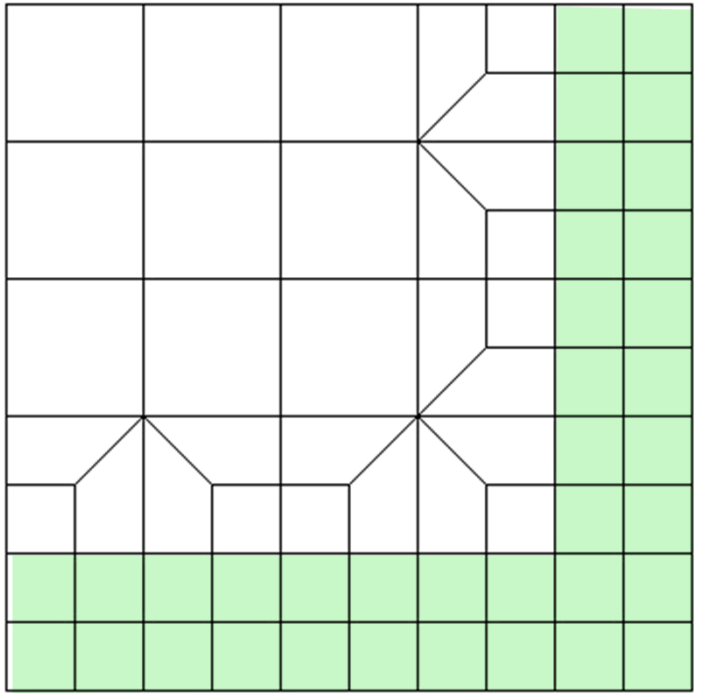


Hex Refinement

3-Refinement



2-Refinement



Hex Refinement

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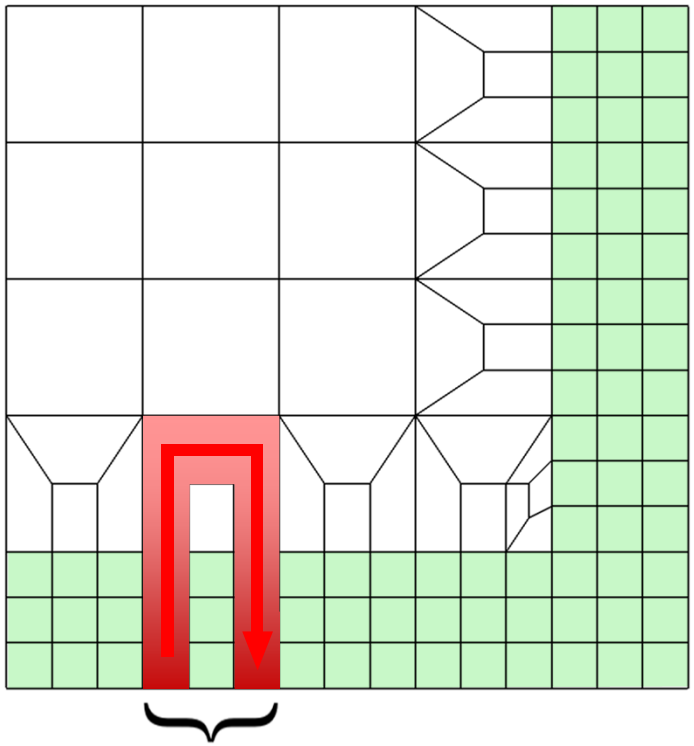
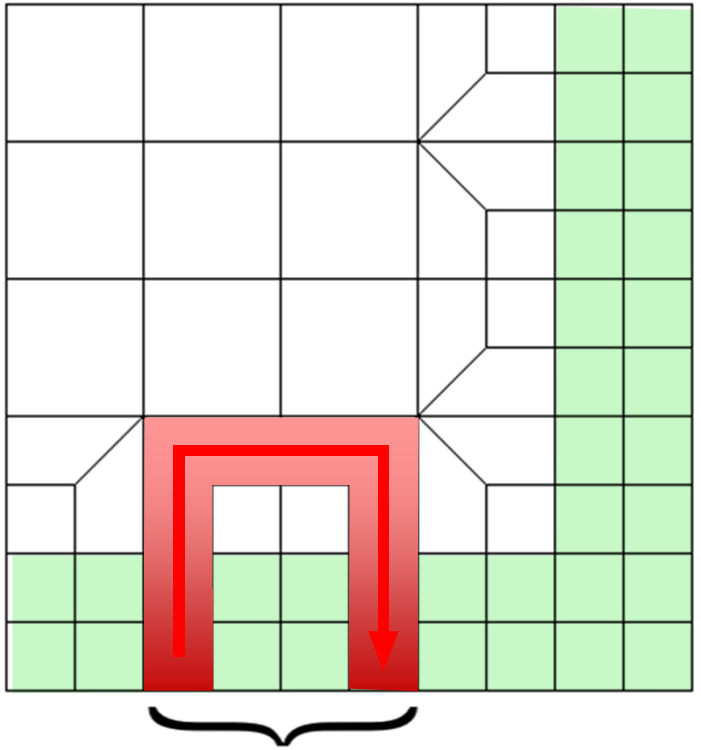
3-Refinement



single element layer

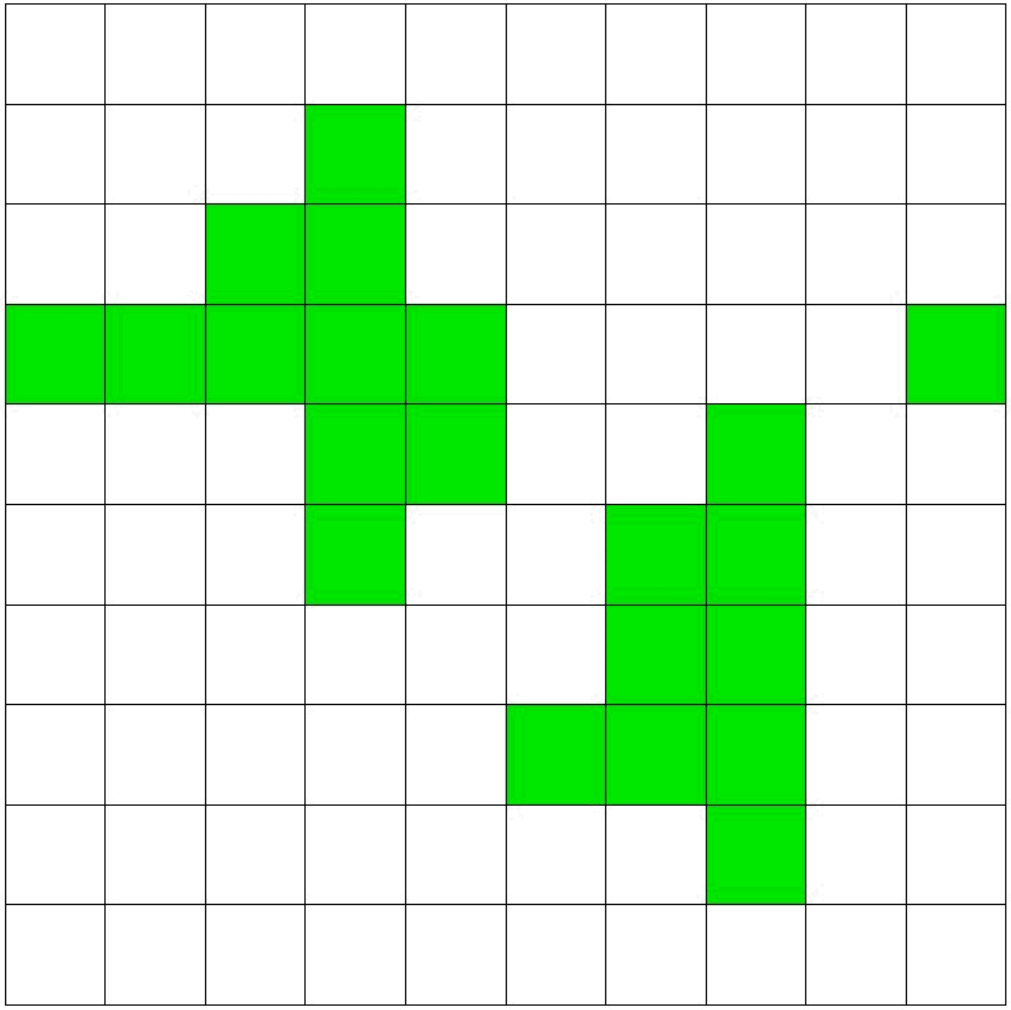
2-Refinement



element layer pair

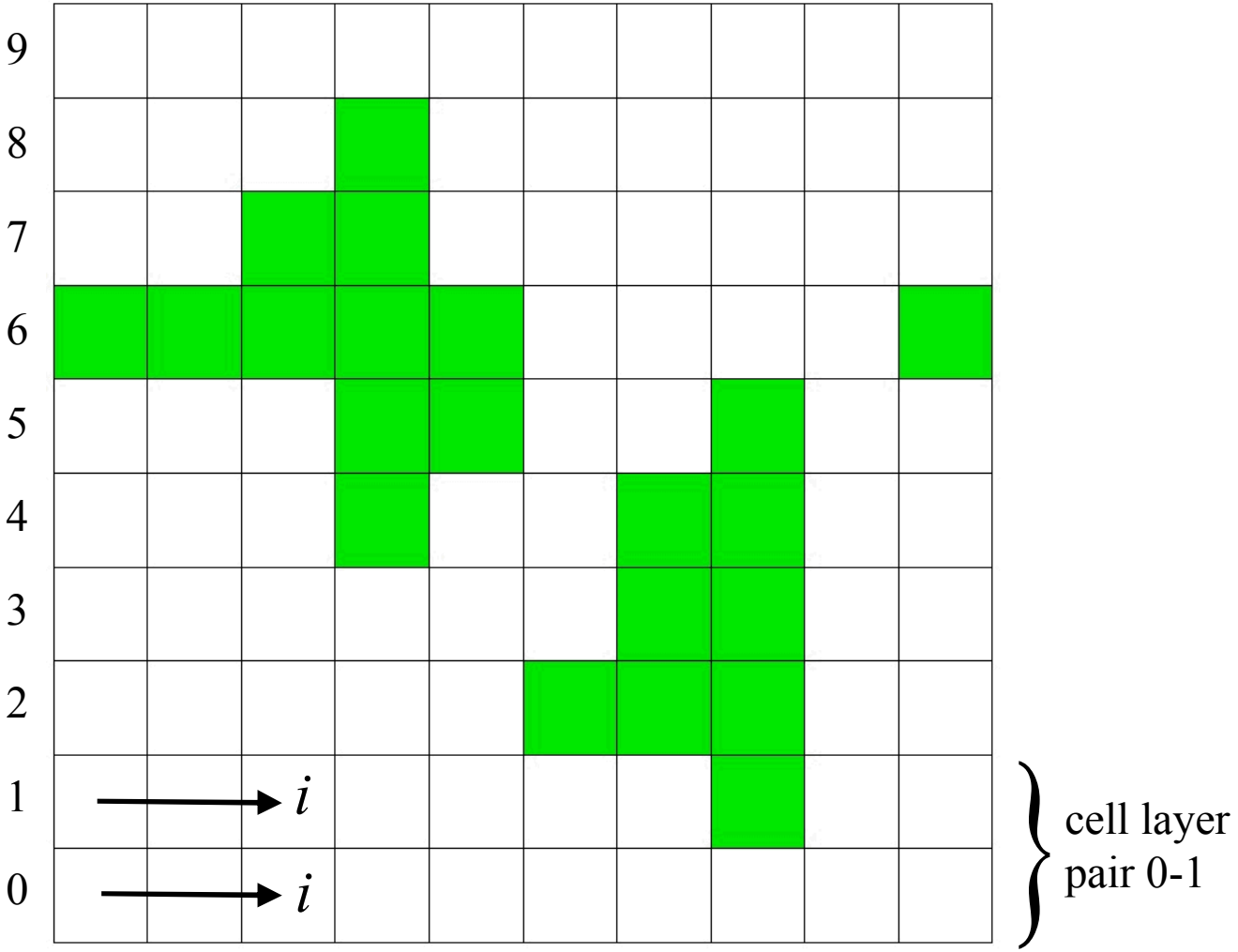
2-Refinement Procedure

2D Example



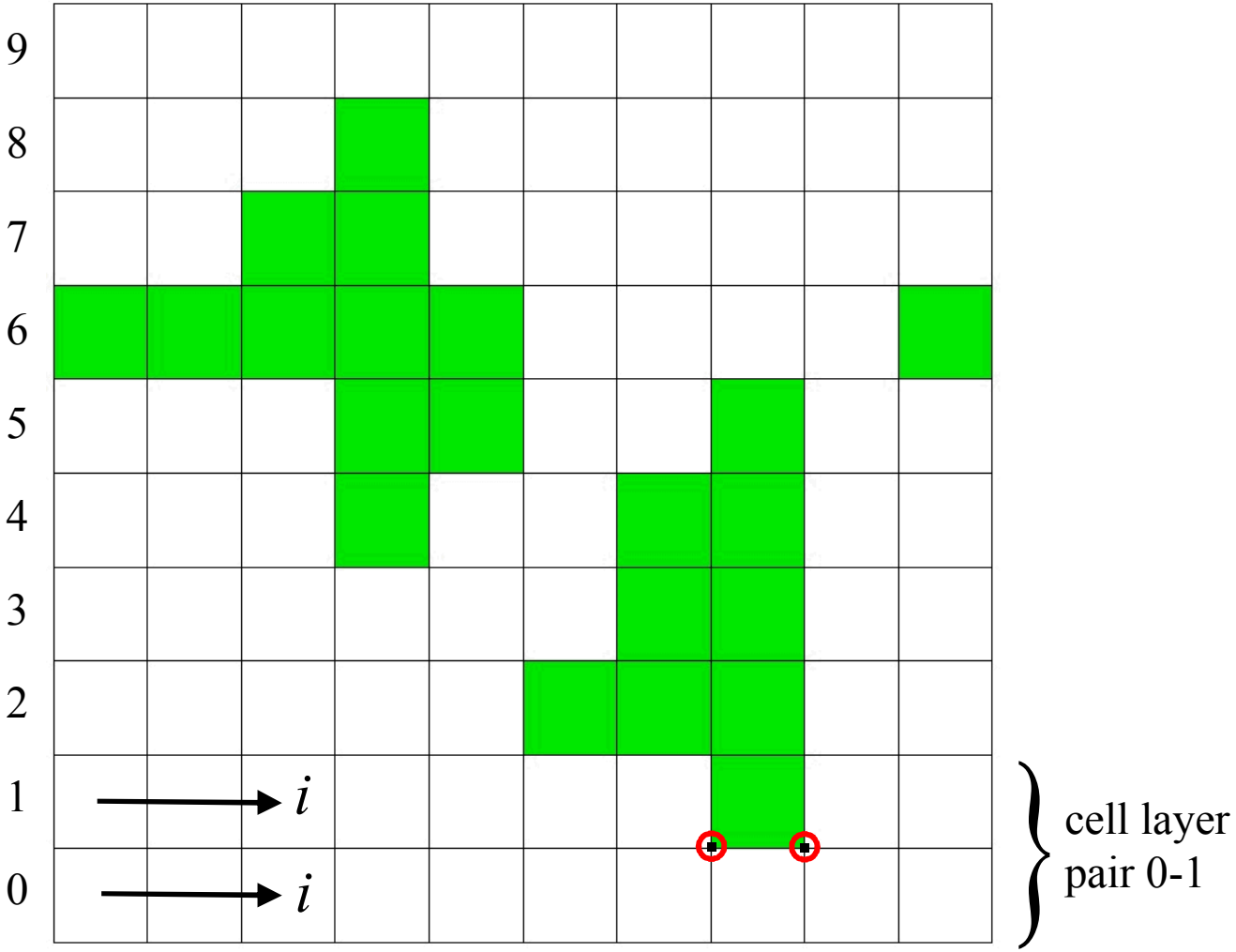
2-Refinement Procedure

2D Example



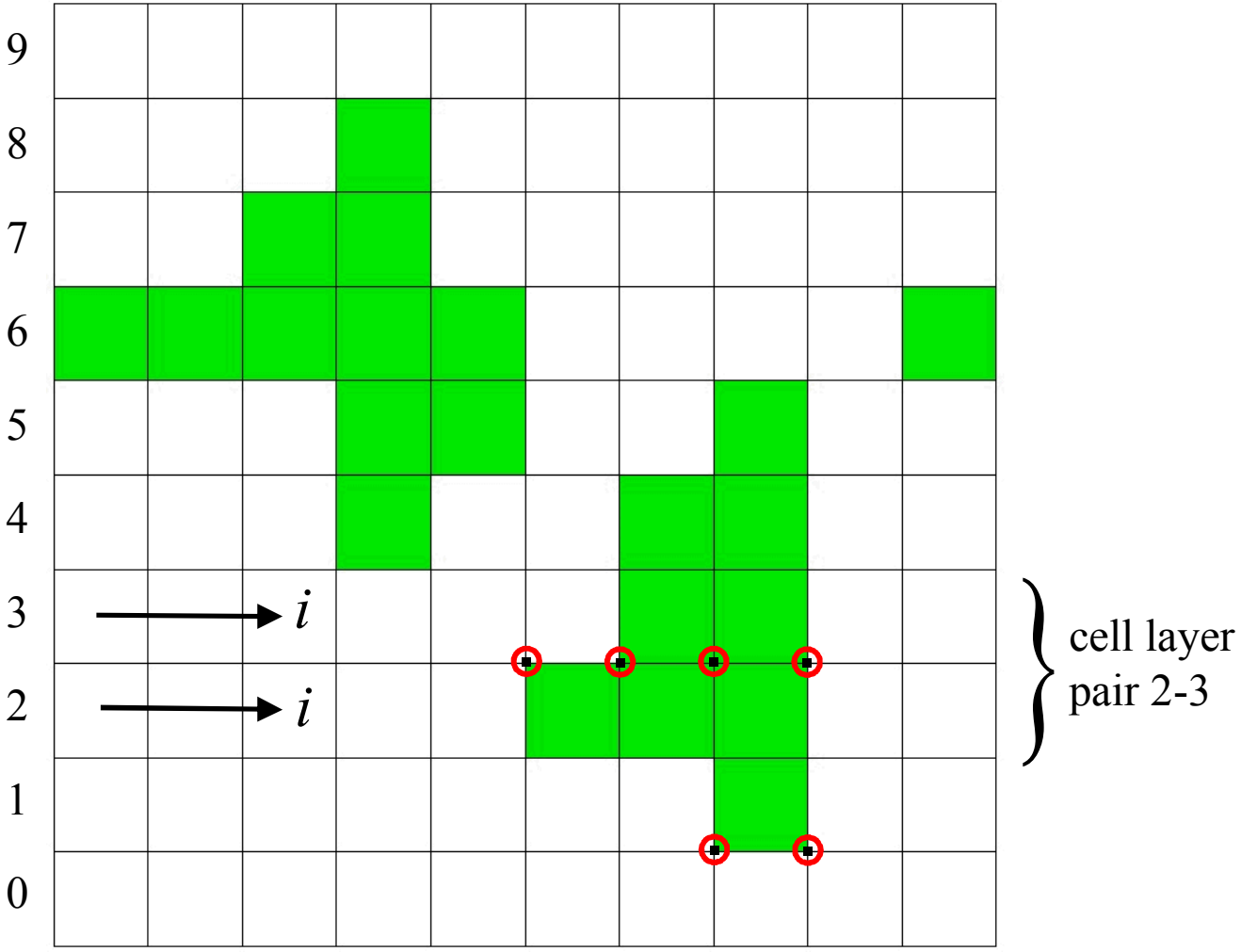
2-Refinement Procedure

2D Example



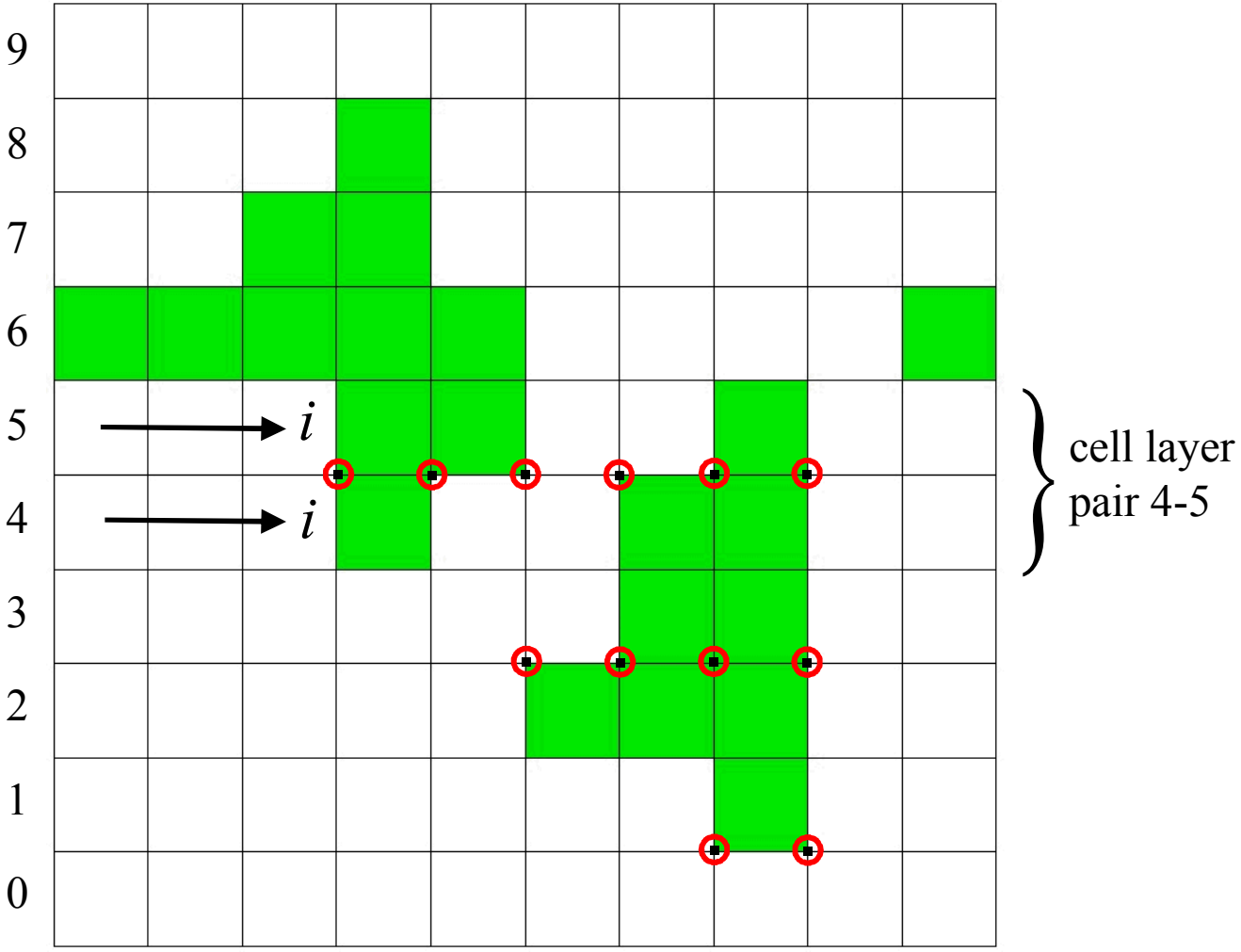
2-Refinement Procedure

2D Example



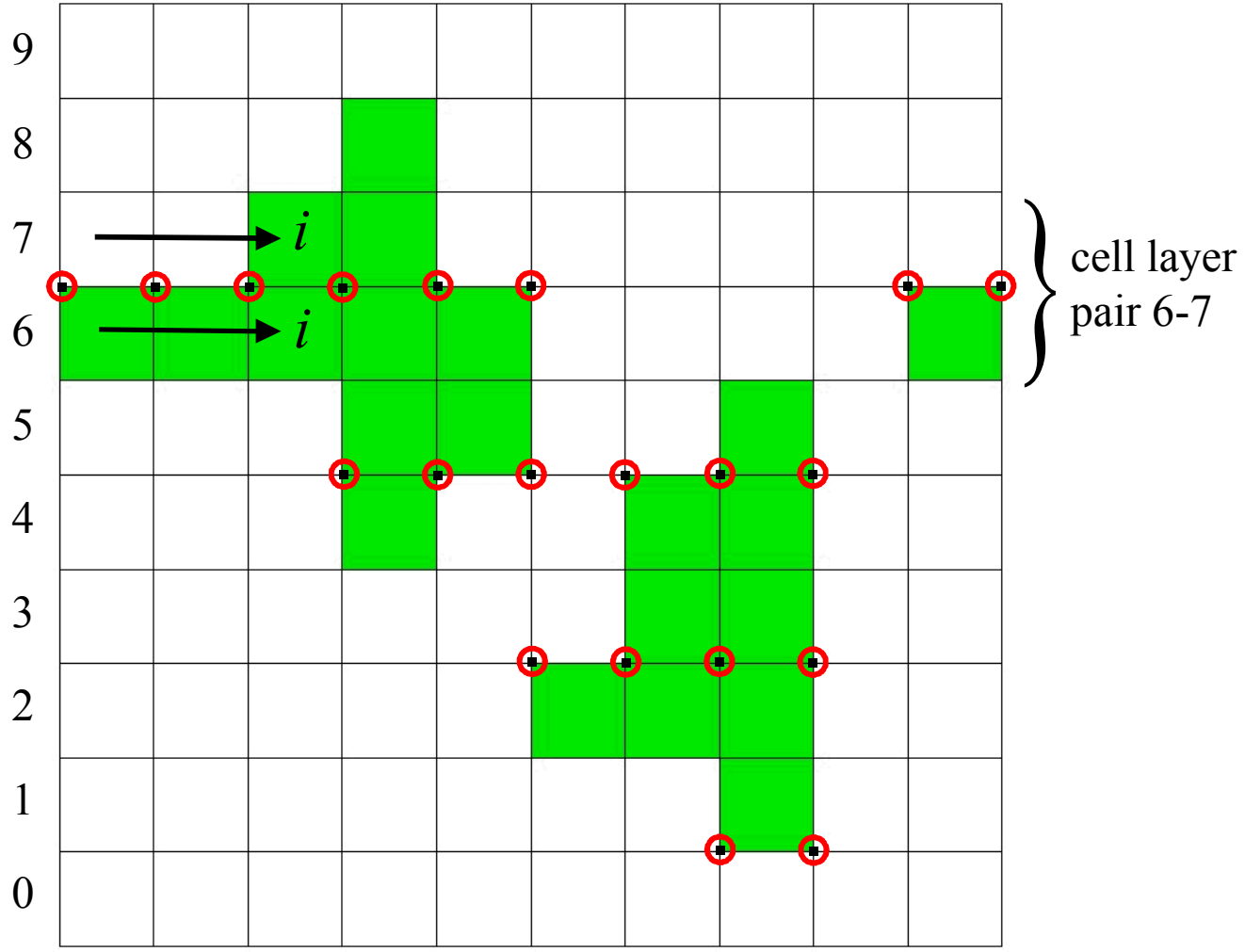
2-Refinement Procedure

2D Example



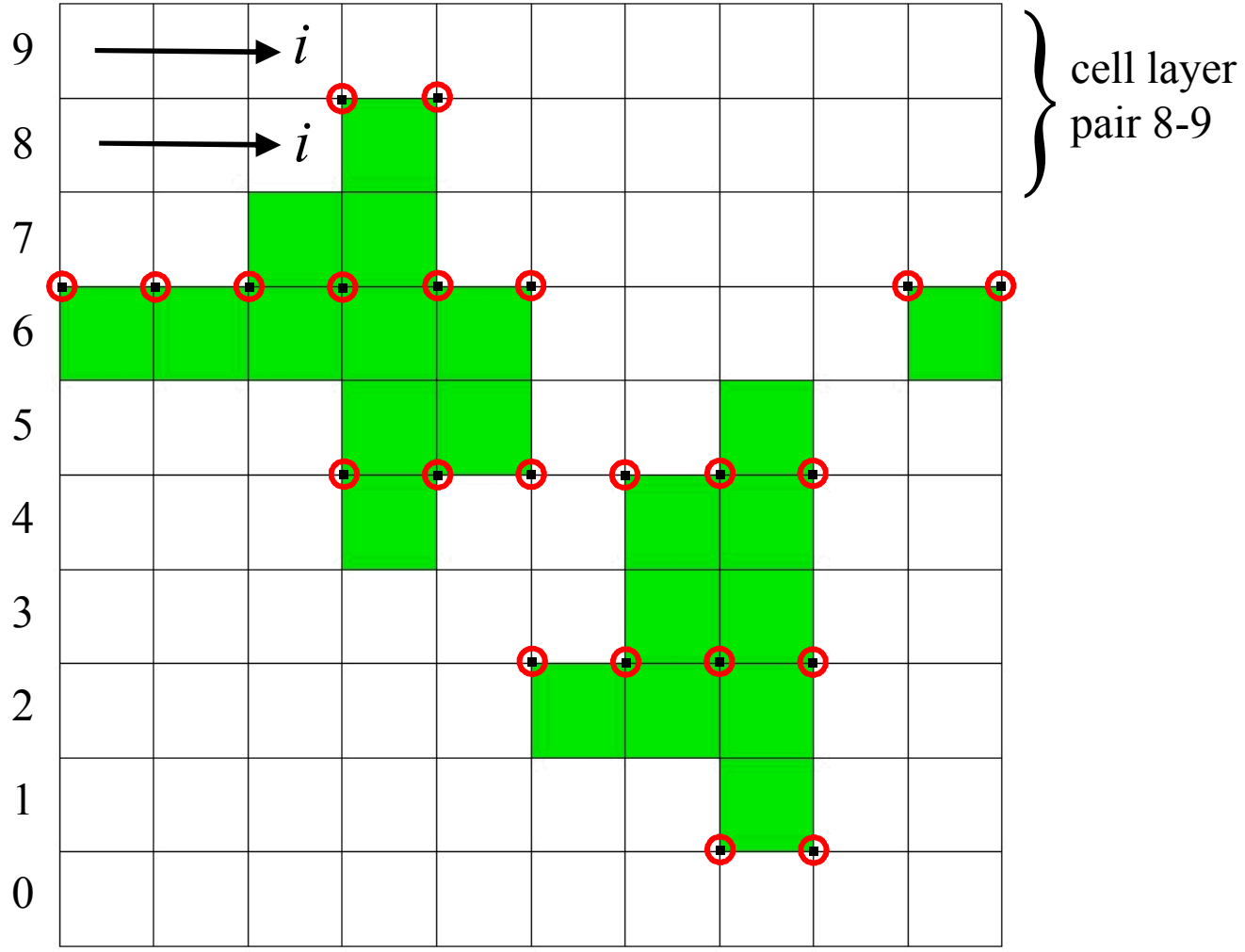
2-Refinement Procedure

2D Example



2-Refinement Procedure

2D Example



2D Templates

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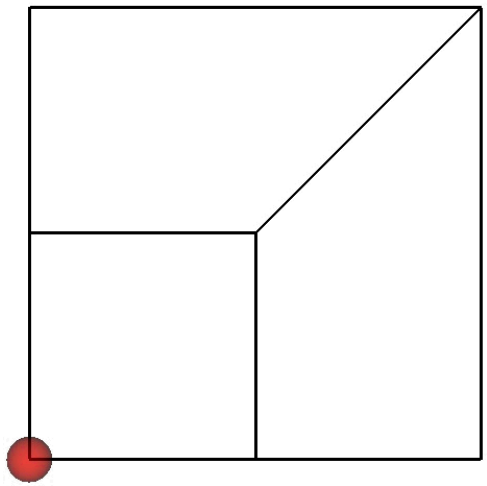

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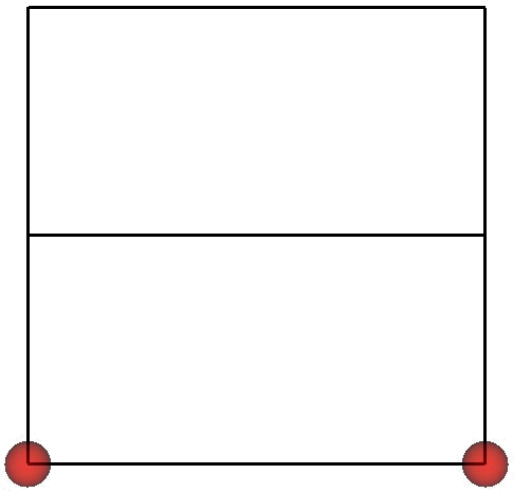
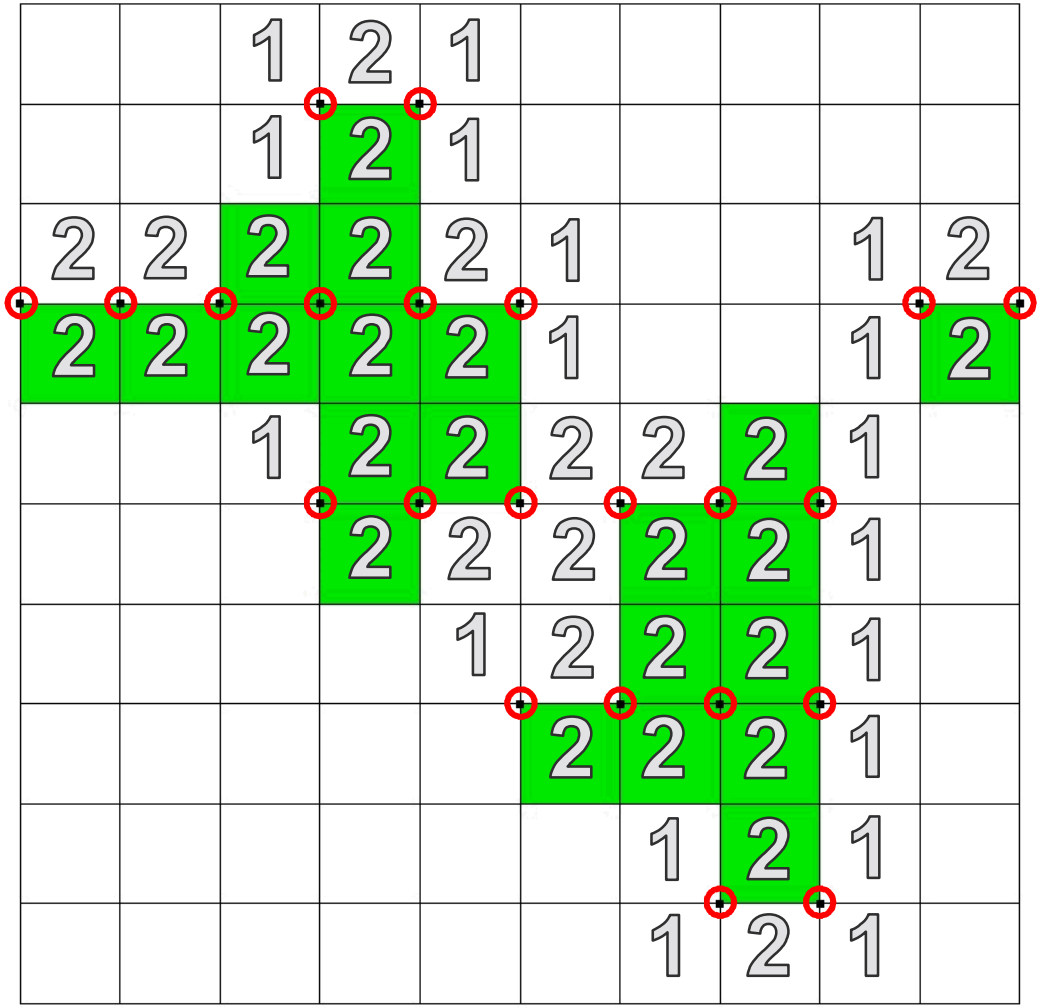


2

2-Refinement Procedure

2D Example



2-Refinement Procedure

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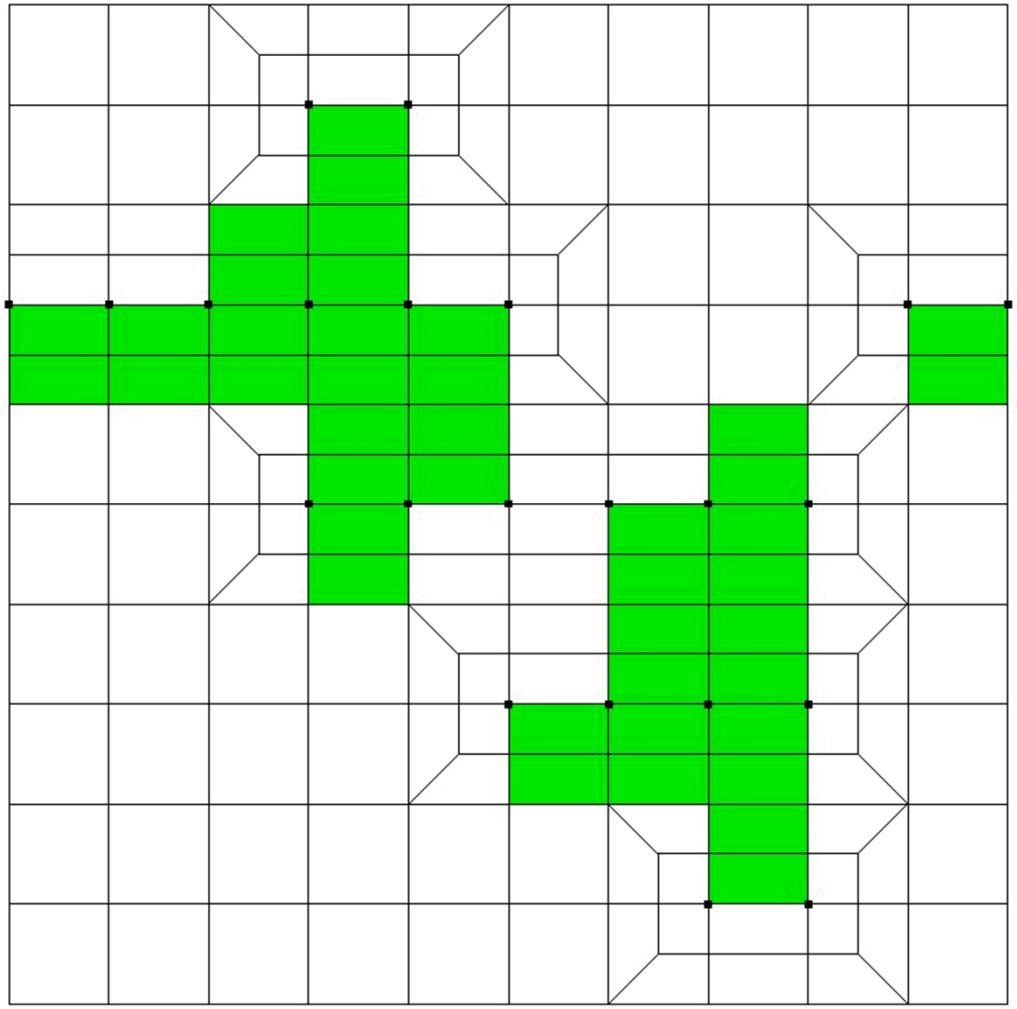
2D Example



2-Refinement Procedure

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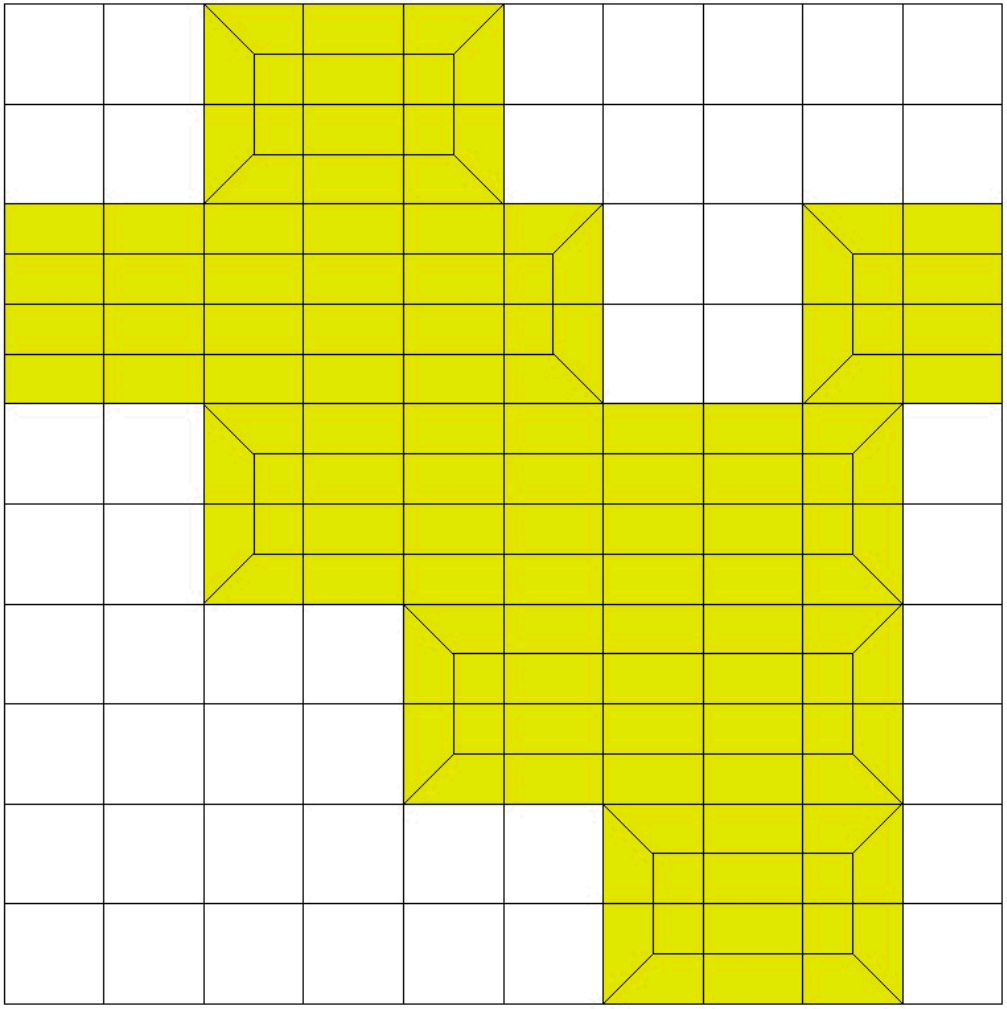
2D Example



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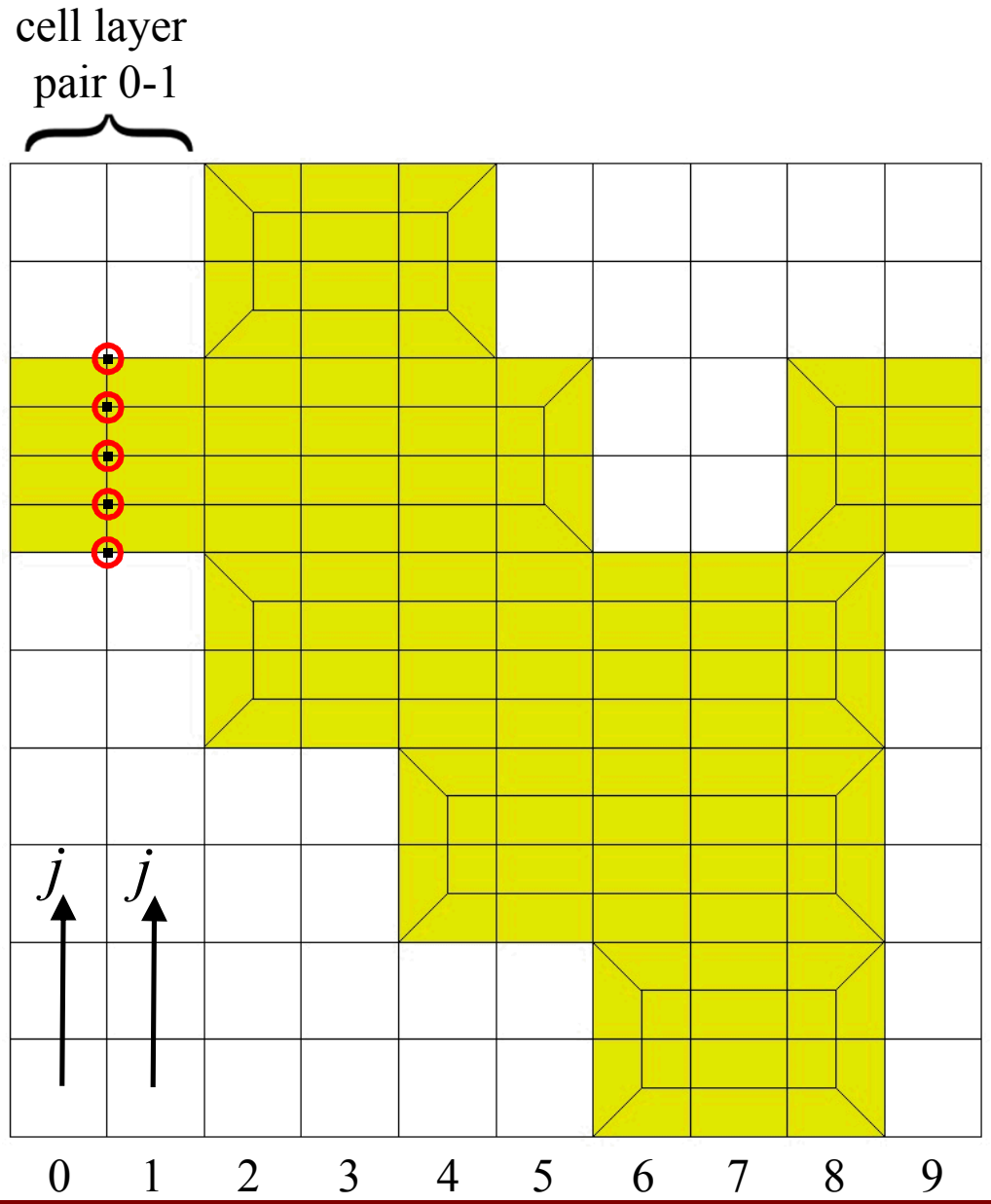

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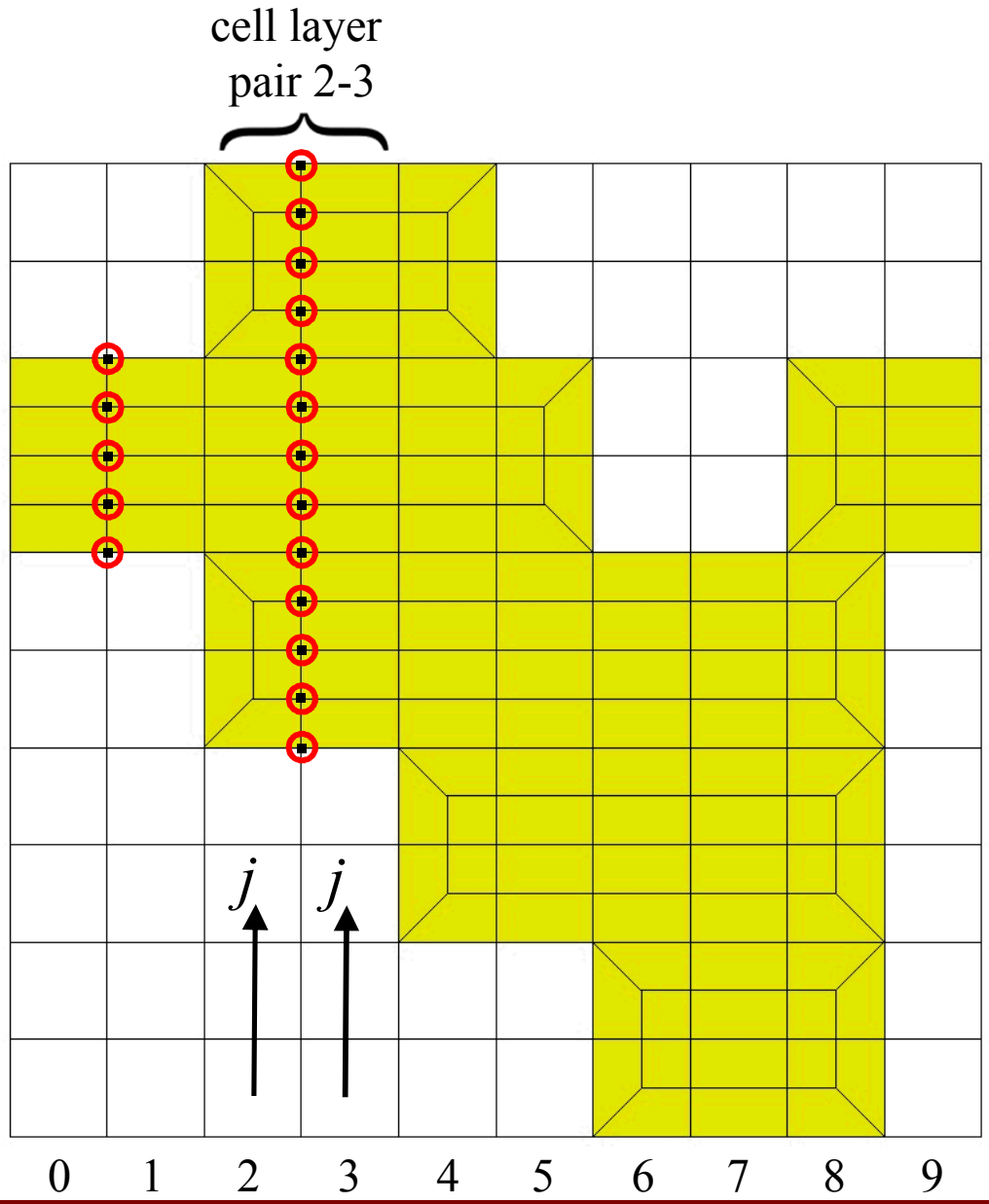
2D Example



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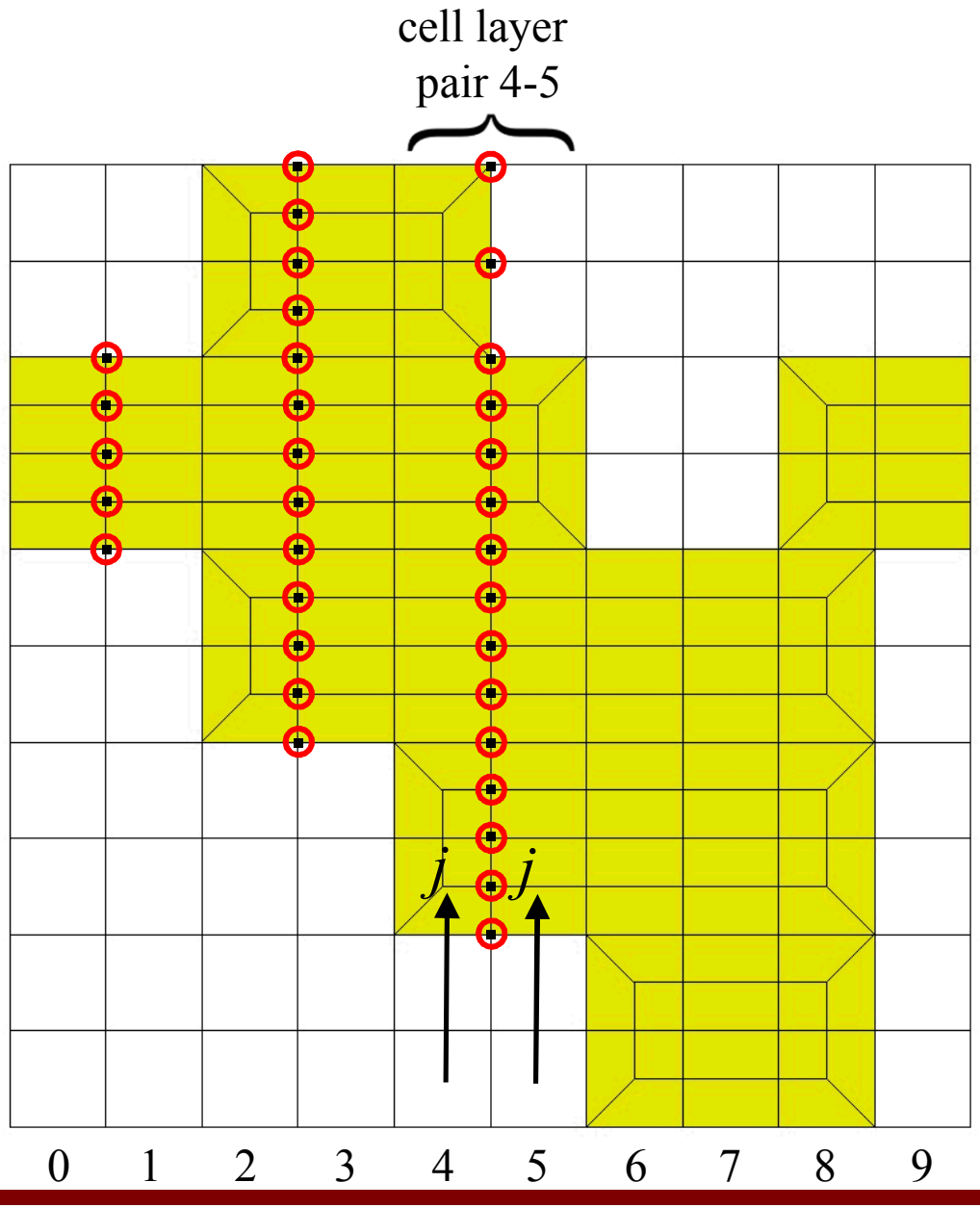

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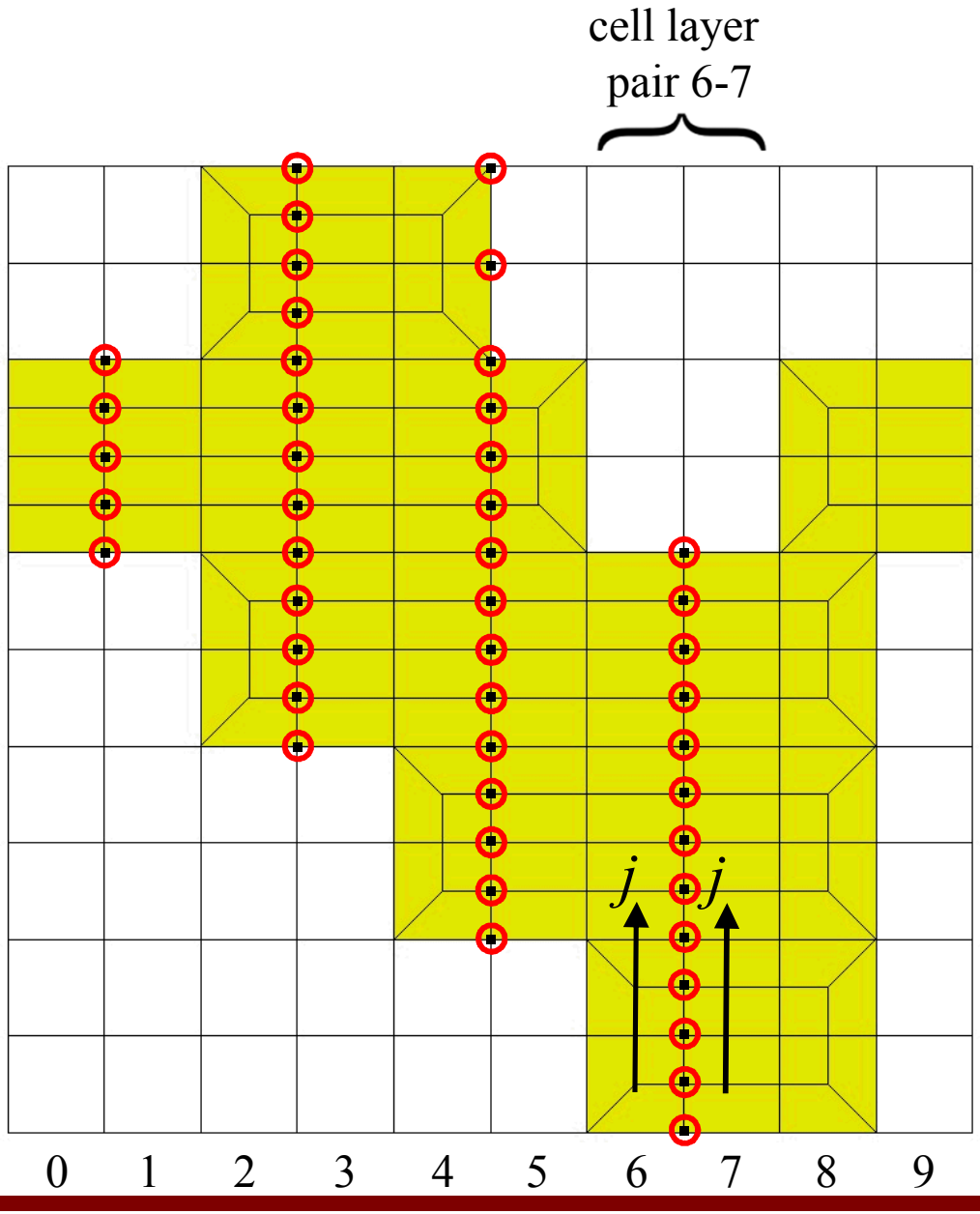

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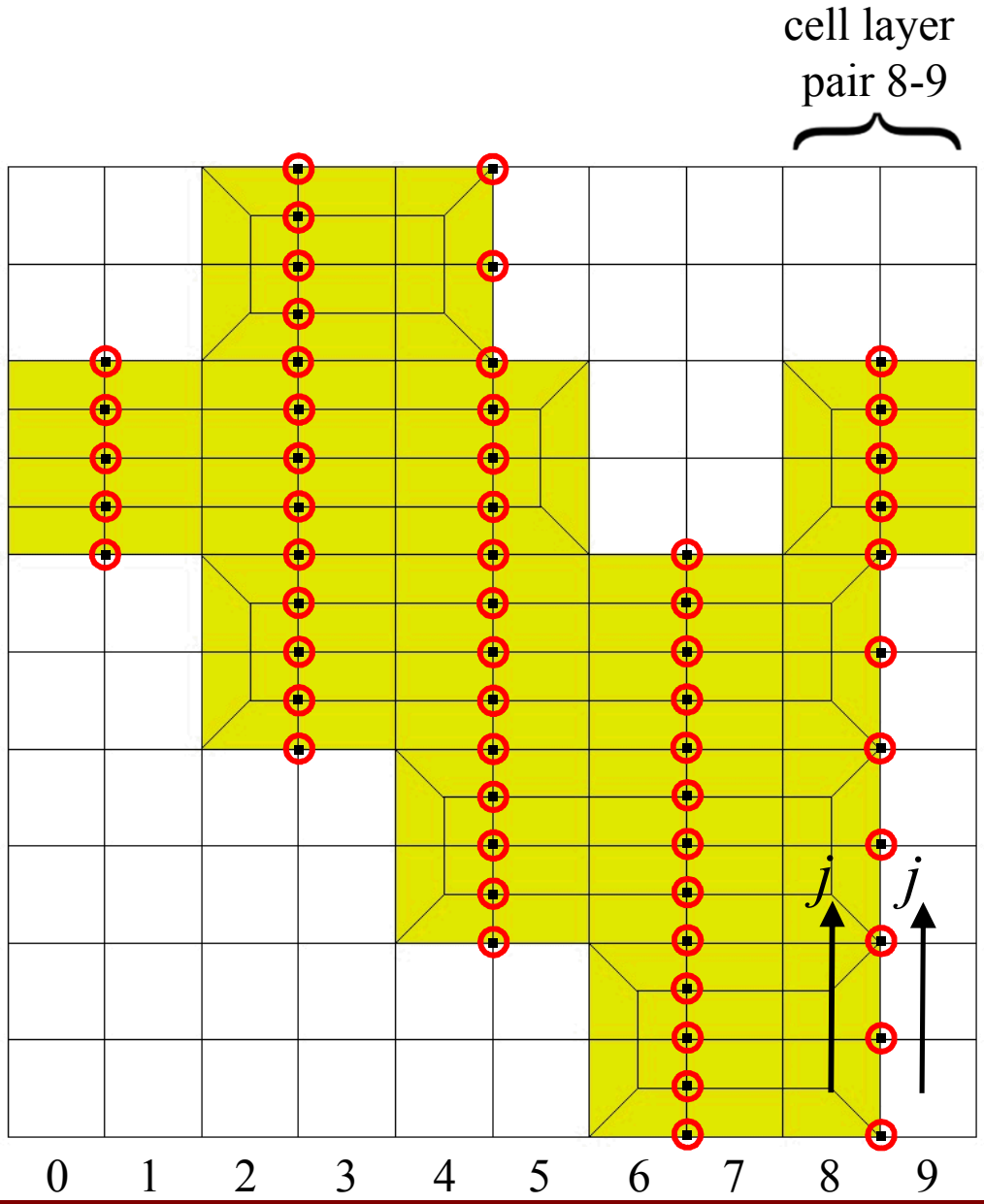
2D Example



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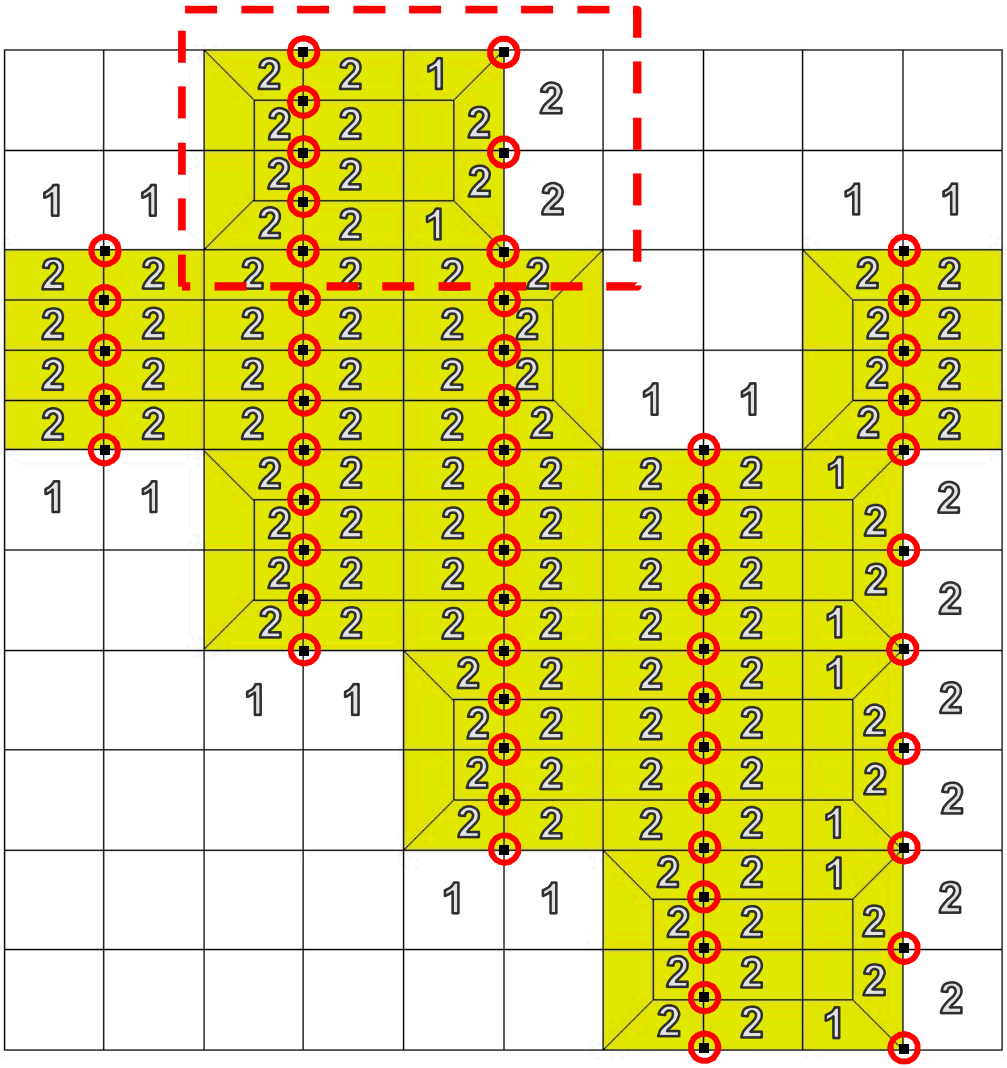

Node Marking Propagation

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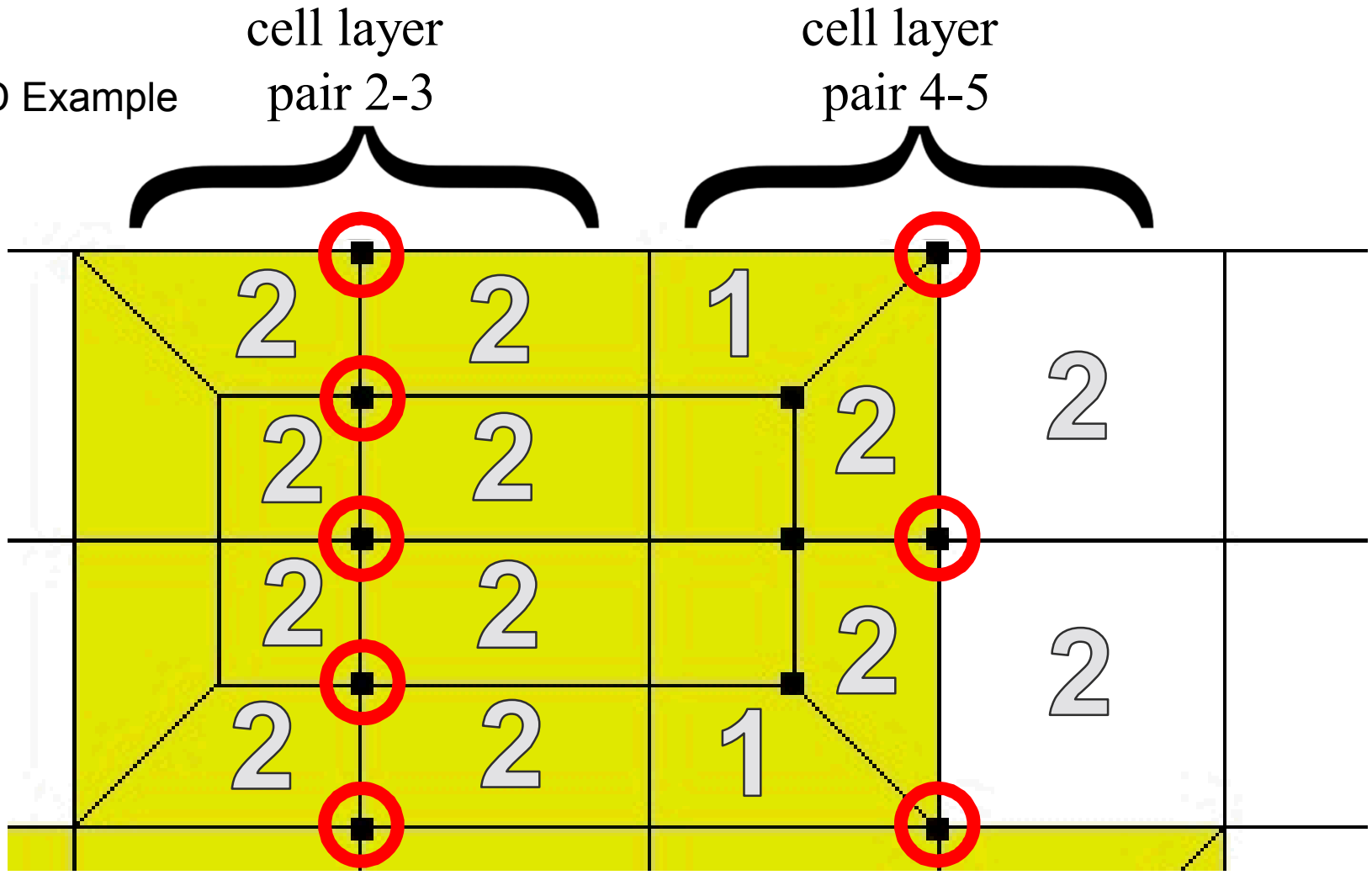

Node Marking Propagation

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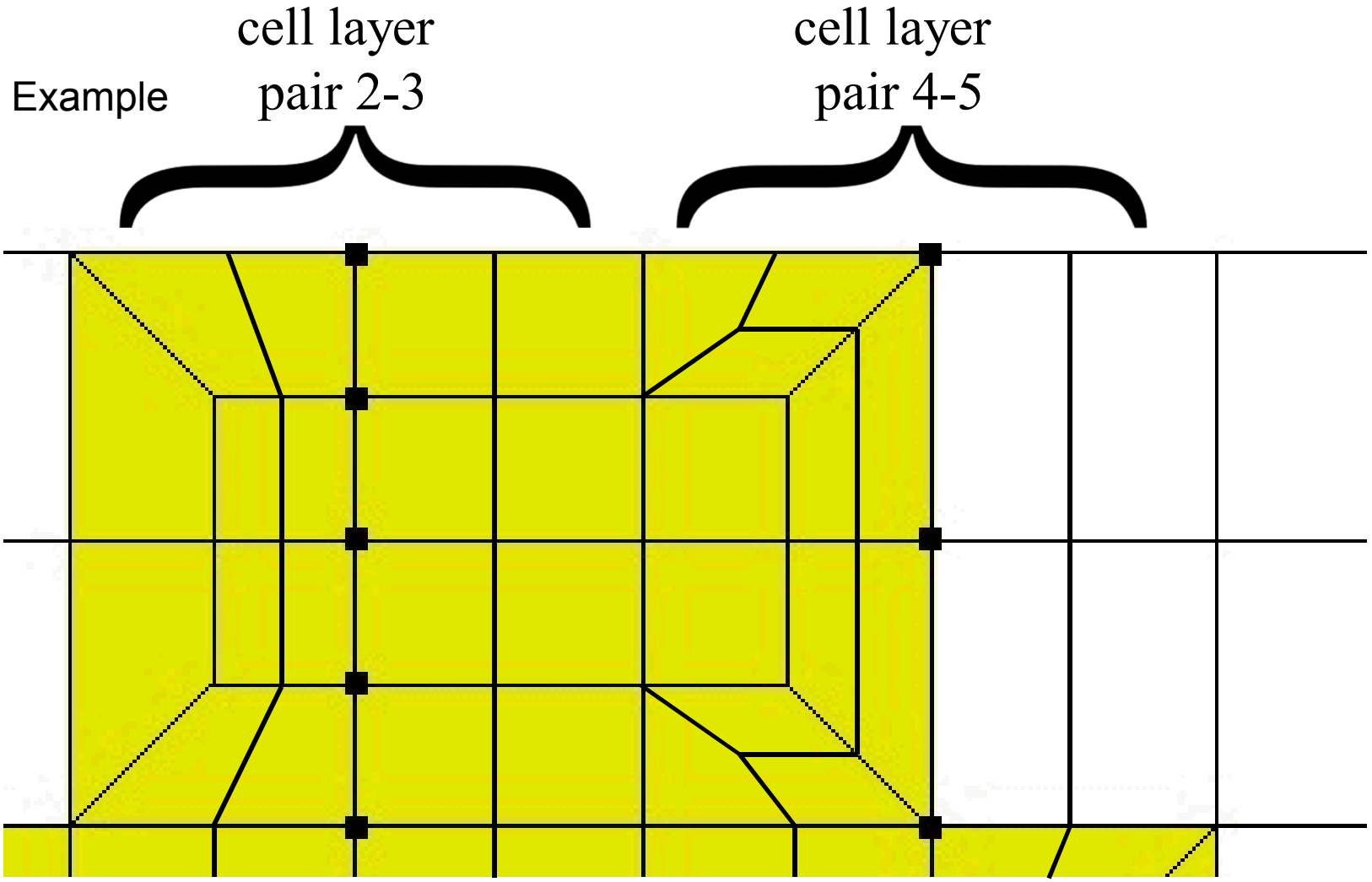

Node Marking Propagation

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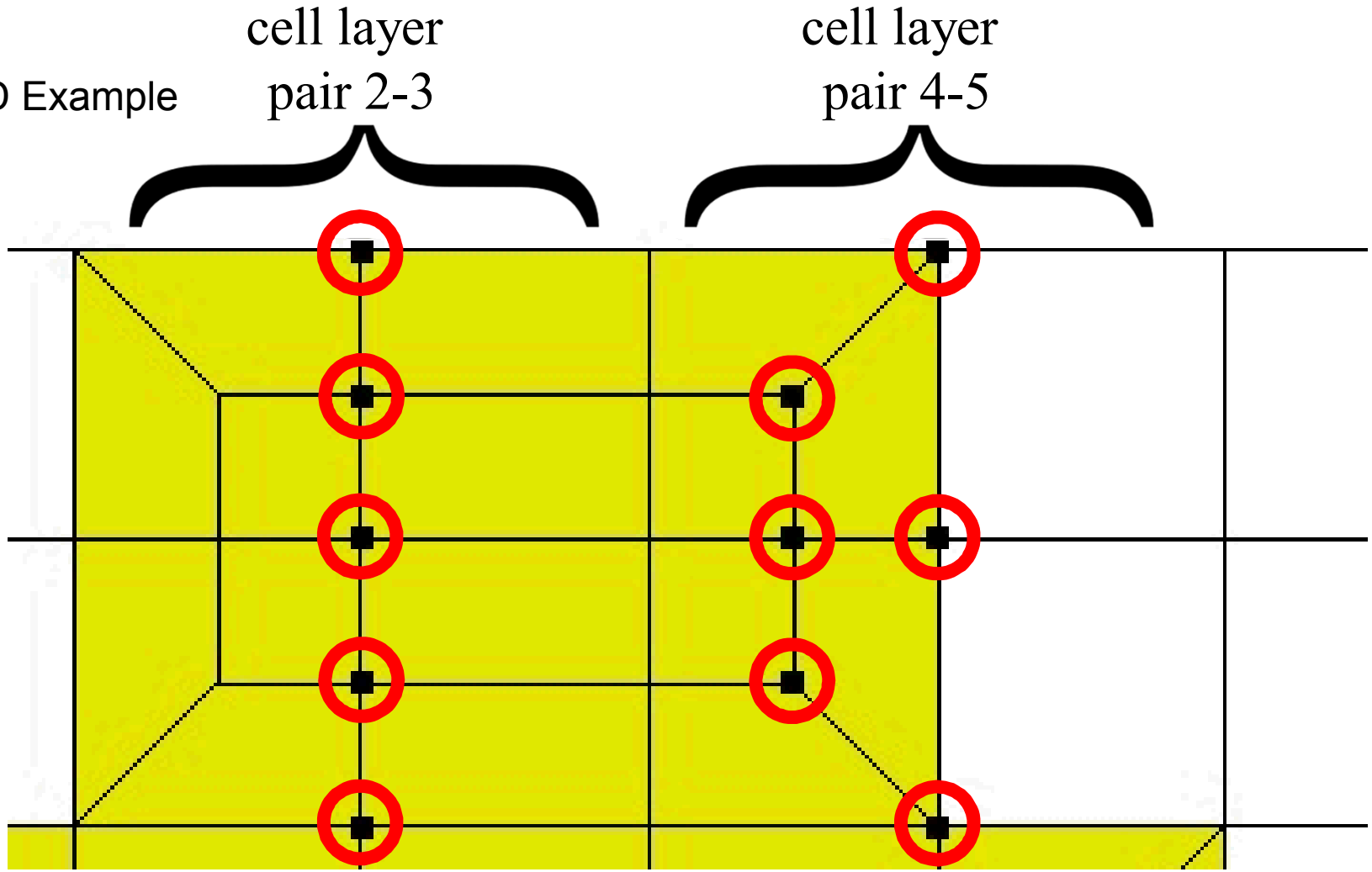

Node Marking Propagation

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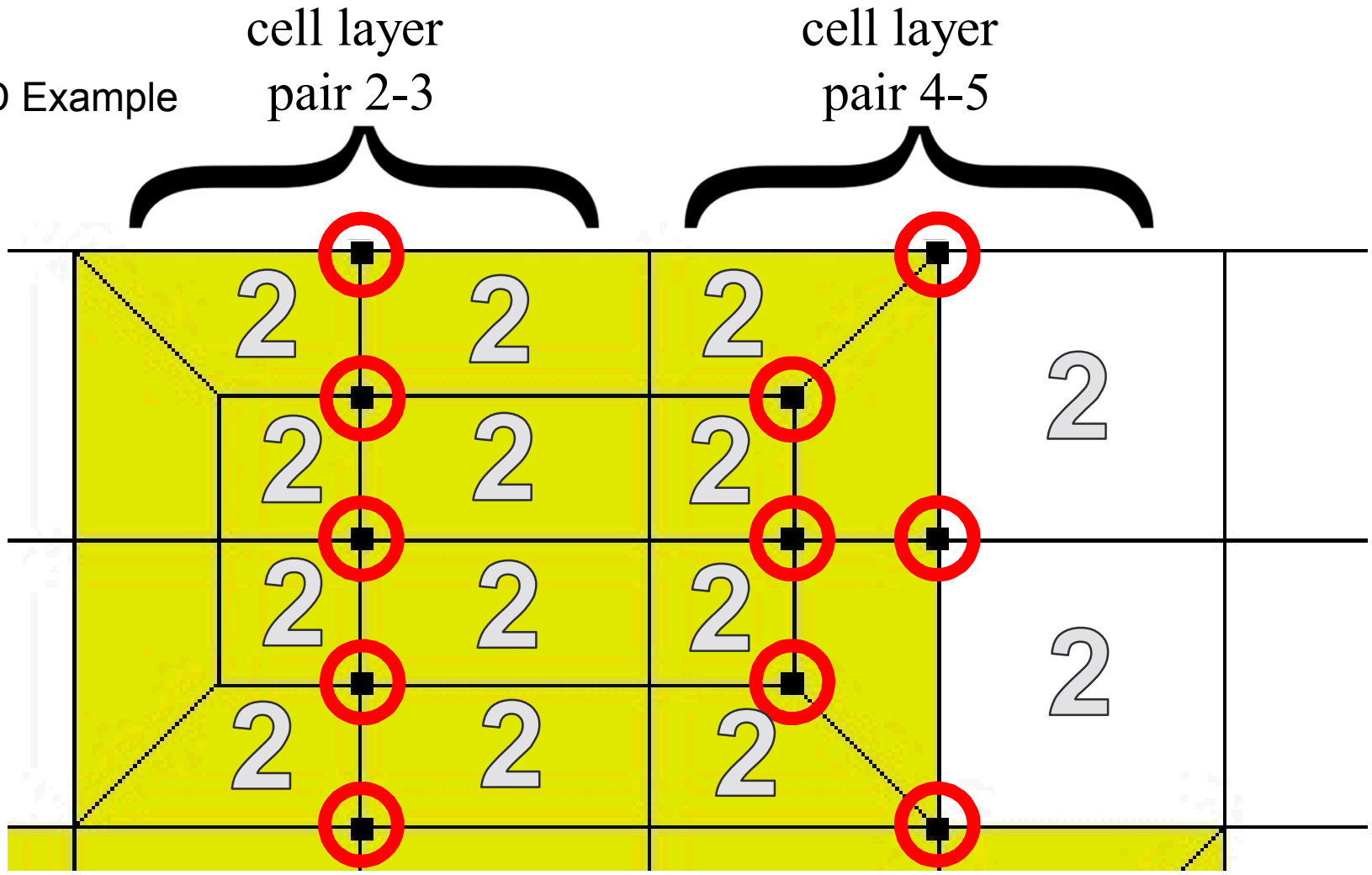

Node Marking Propagation

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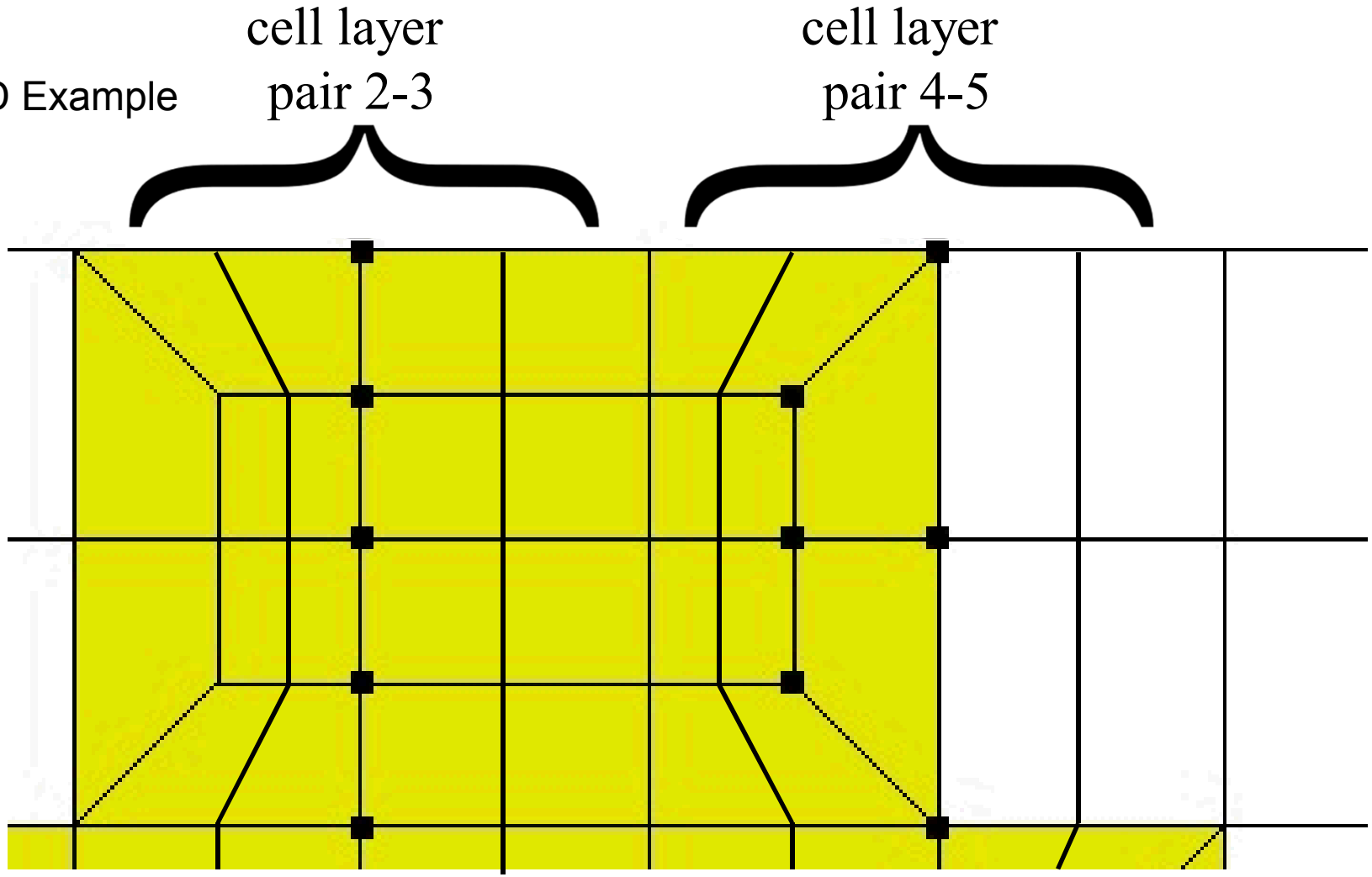

2-Refinement Procedure

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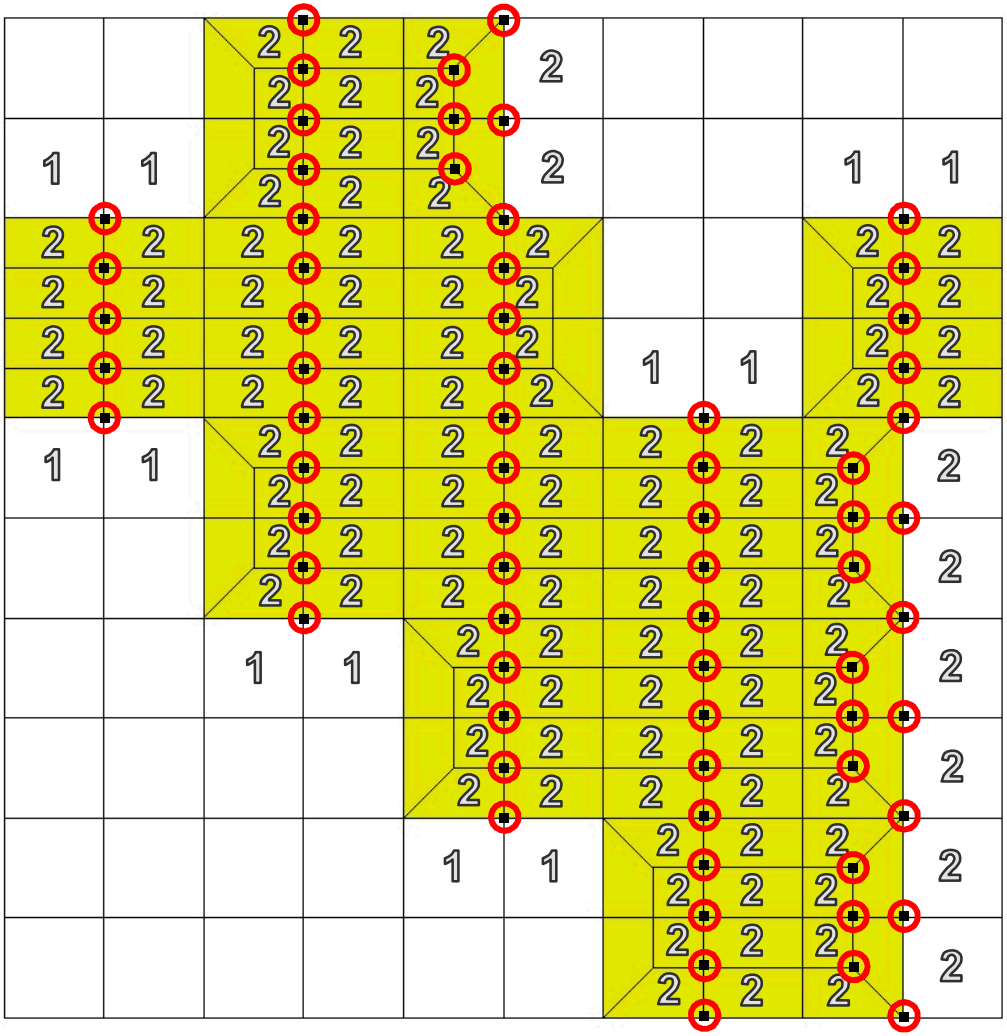

2-Refinement Procedure

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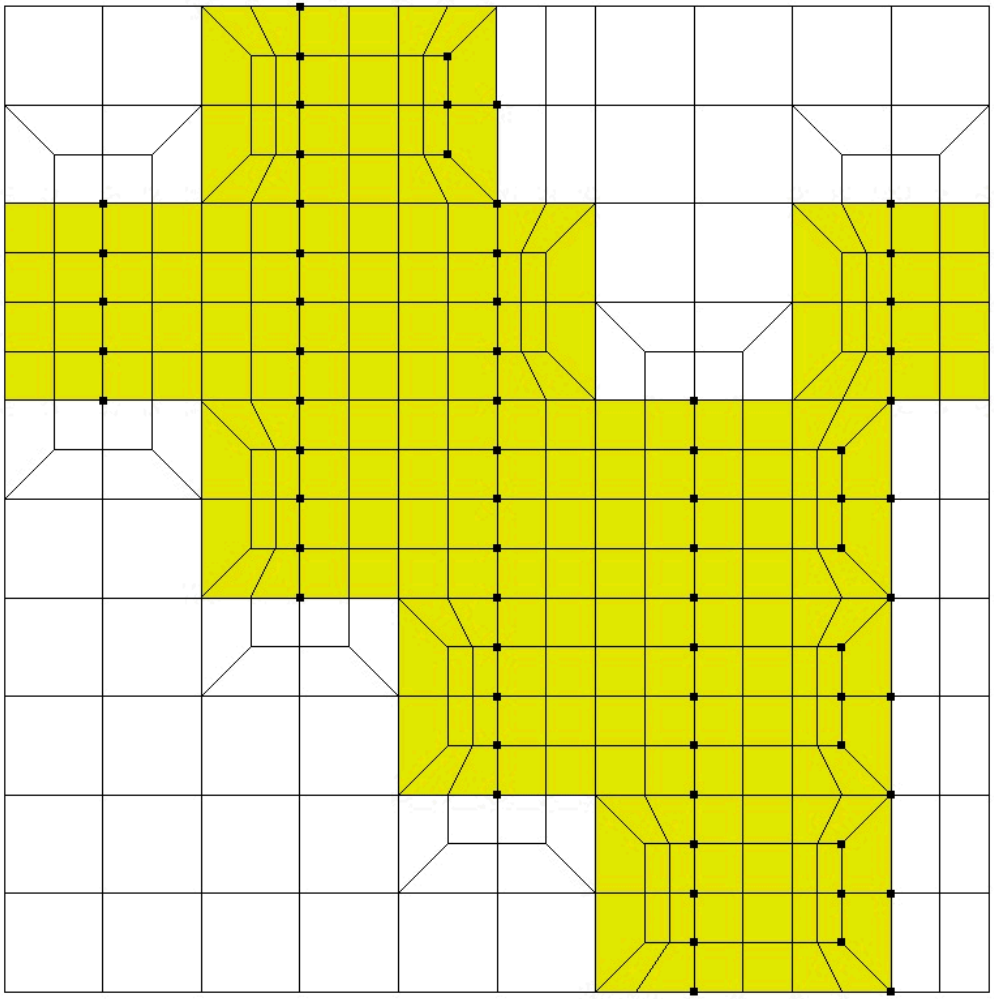
2D Example



2-Refinement Procedure

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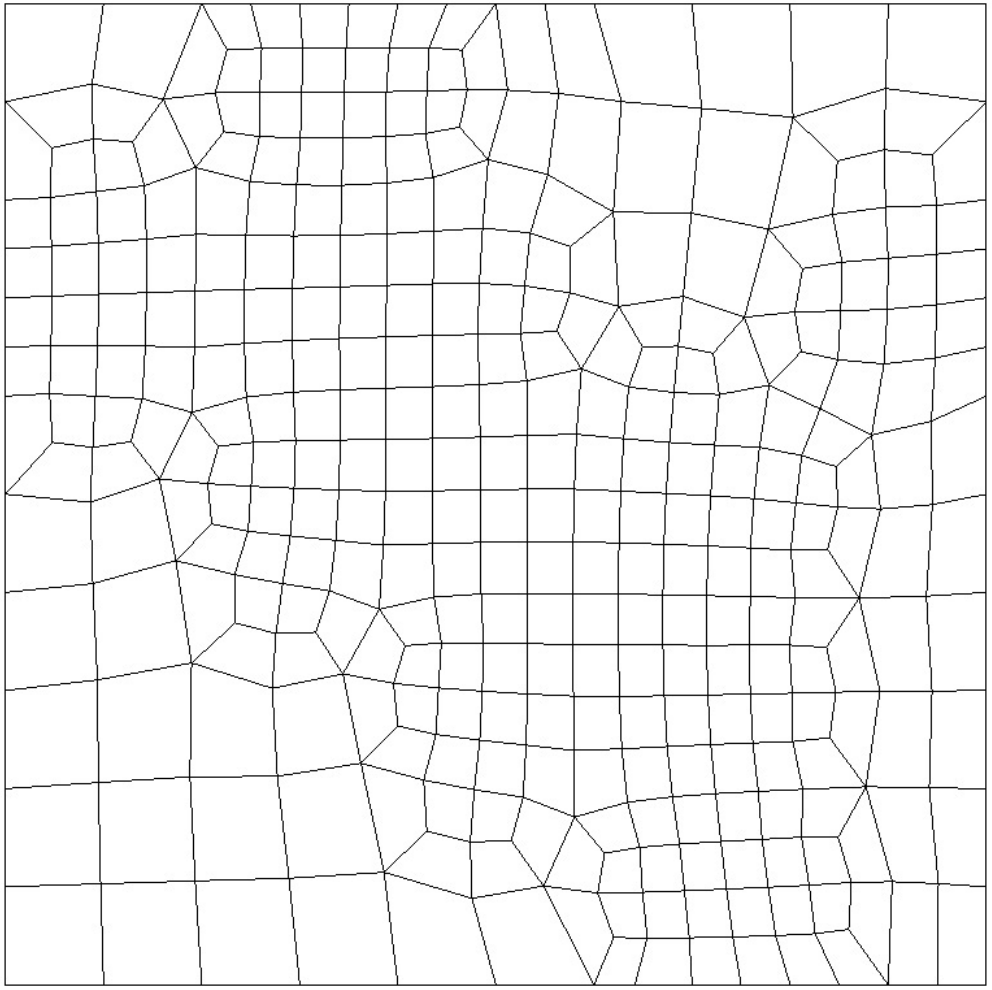
2D Example



2-Refinement Procedure

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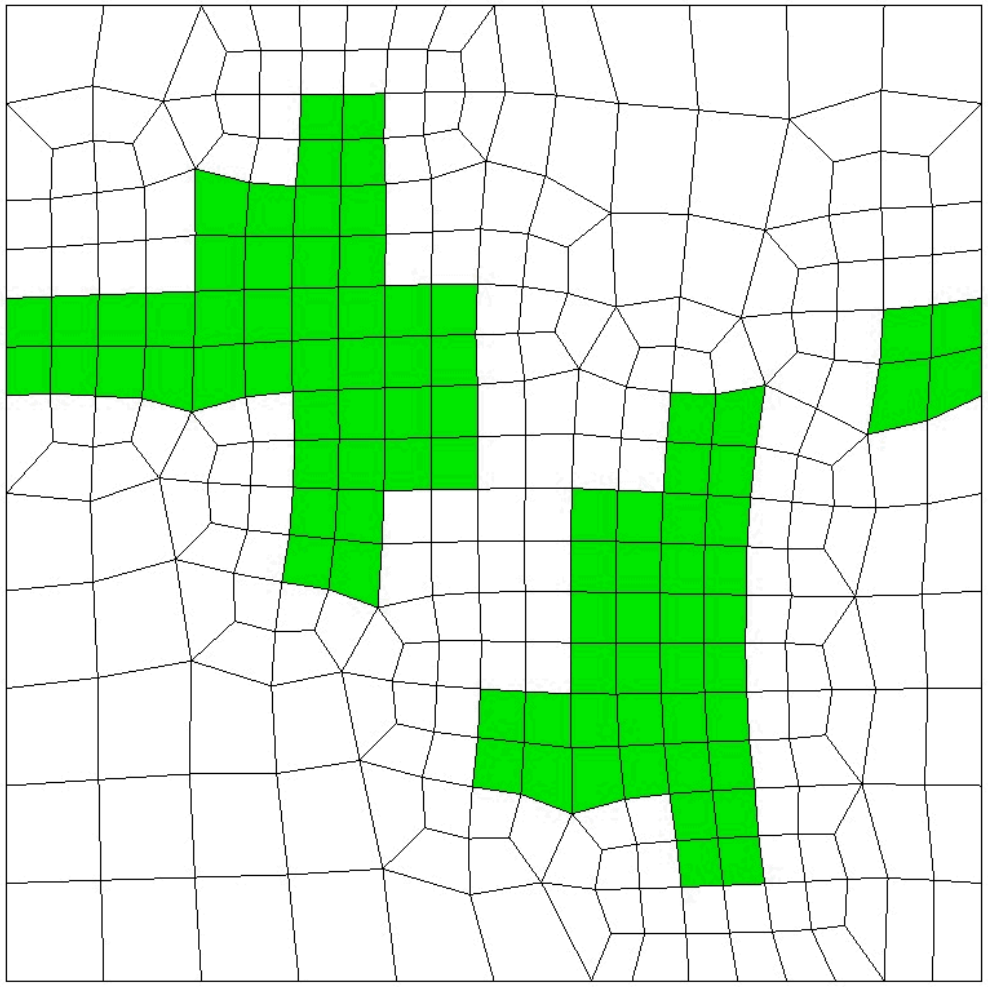
2D Example



2-Refinement Algorithm

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Enumerate Cartesian grid

Identify and mark elements to be uniformly refined

For each direction *I, J, K* do

- Mark nodes between odd-even layers at marked elements
- Apply refinement templates to elements with marked nodes
- Expand marked elements to include refined elements

End For

2-Refinement Procedure

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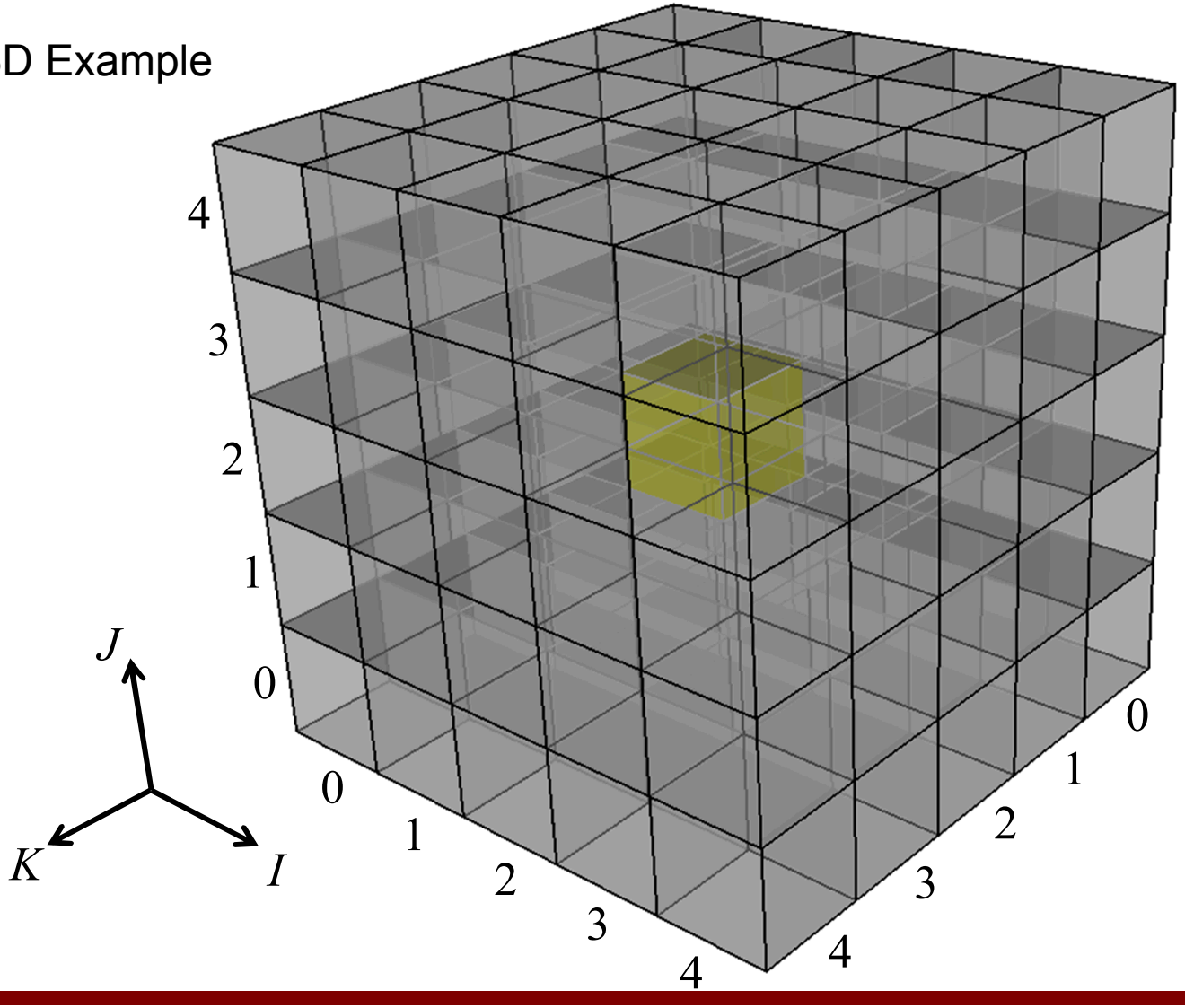
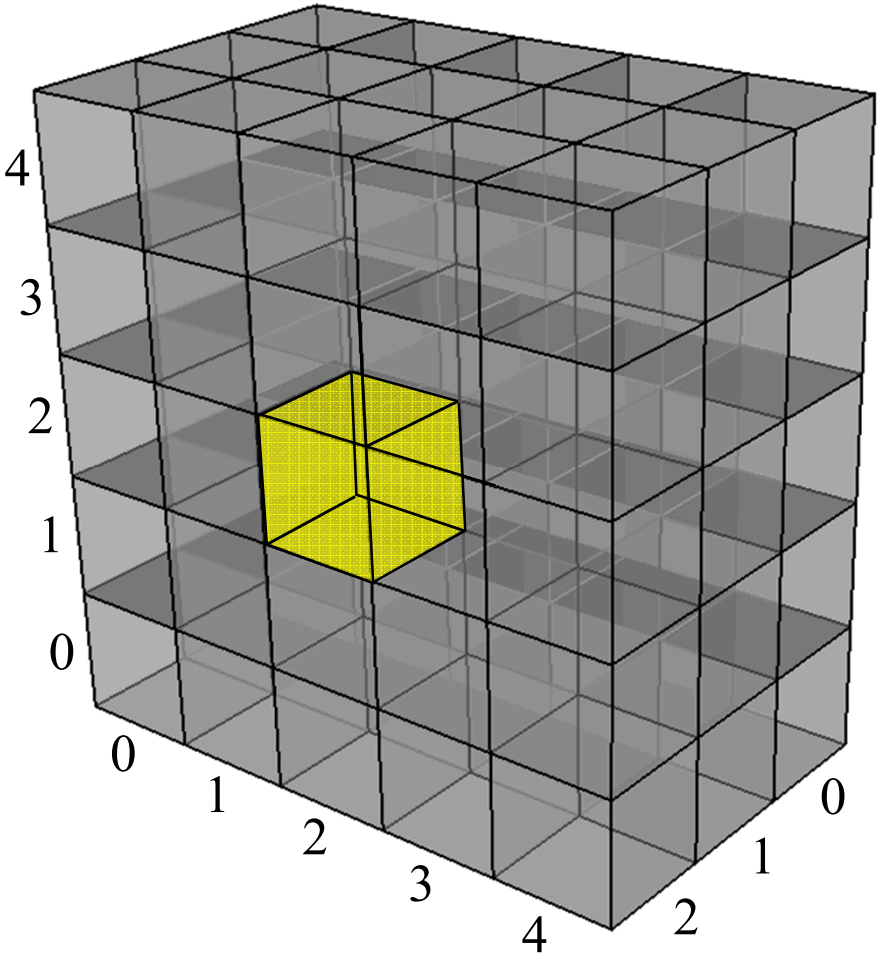
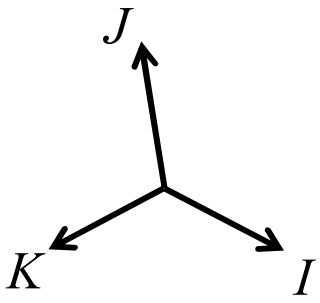
3D Example



2-Refinement Procedure

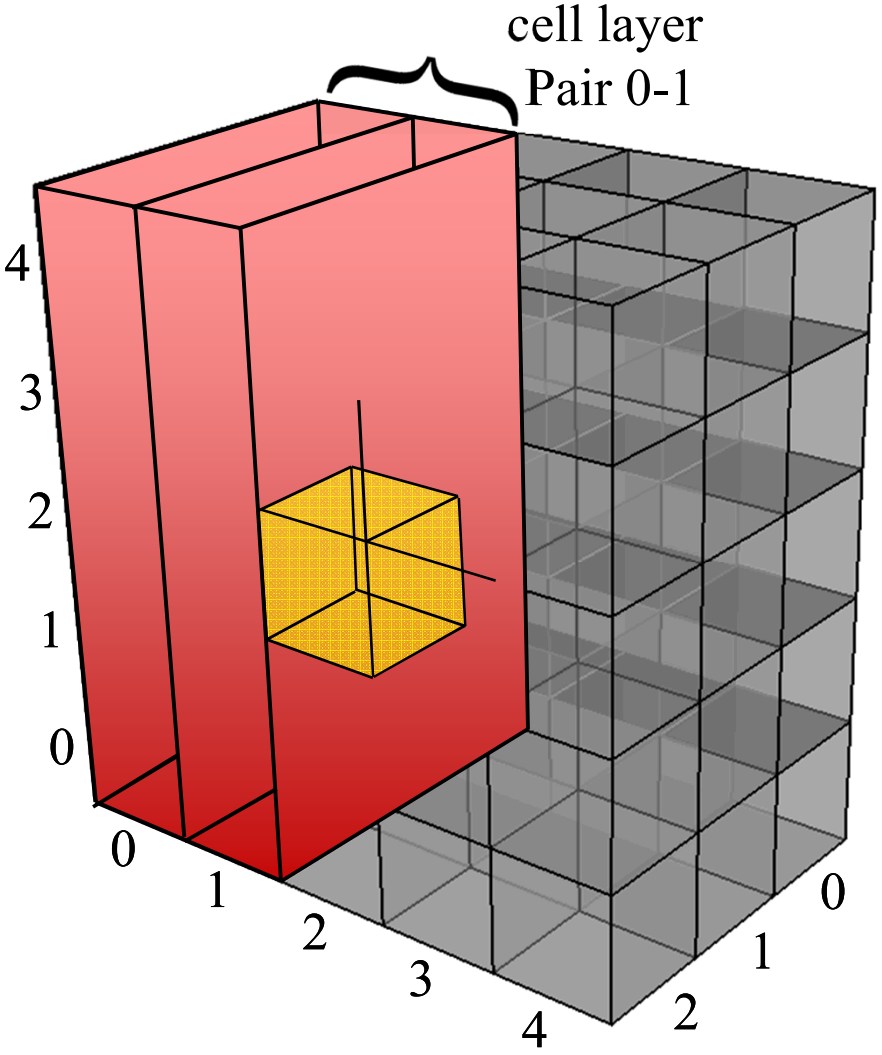
3D Example

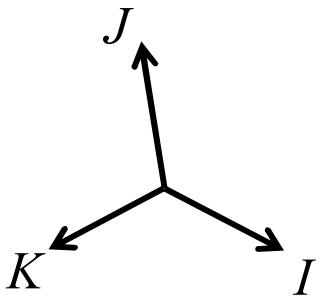




2-Refinement Procedure

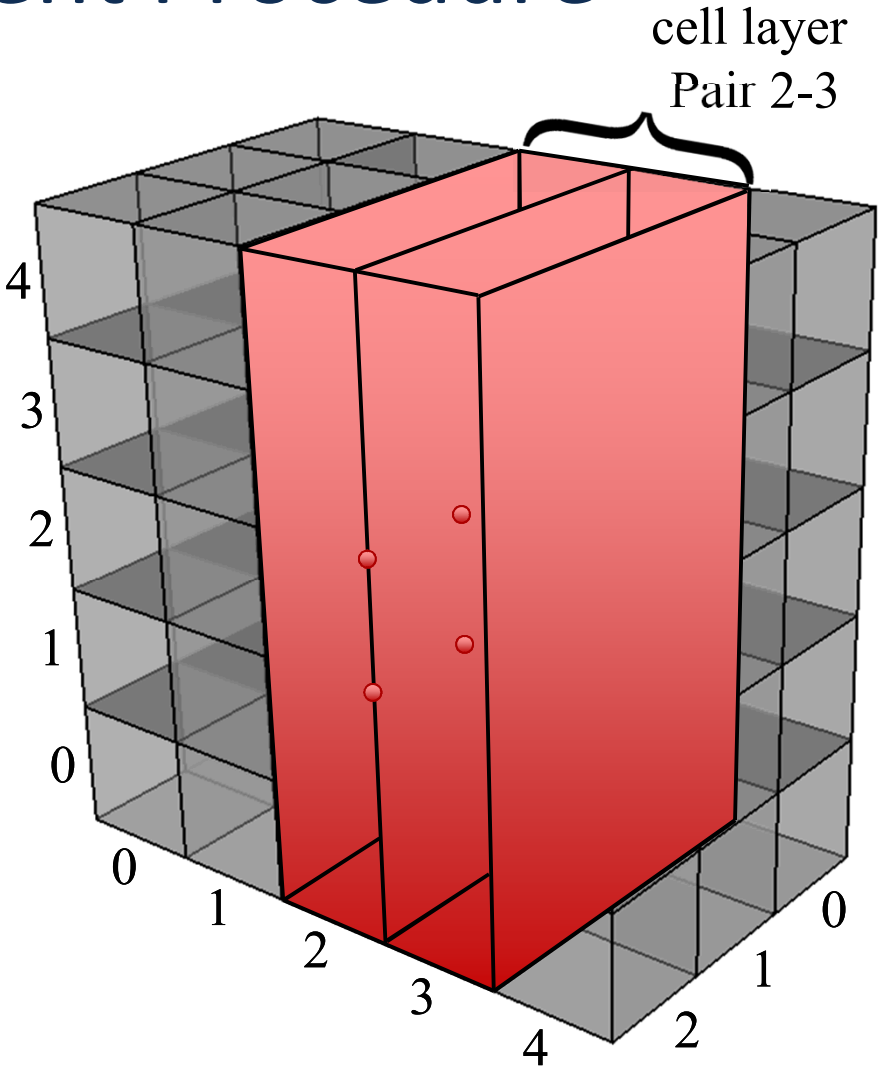
3D Example

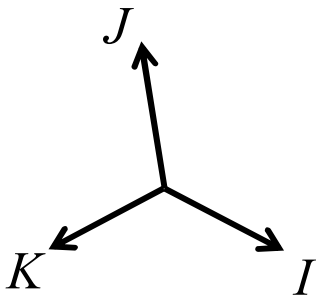




2-Refinement Procedure

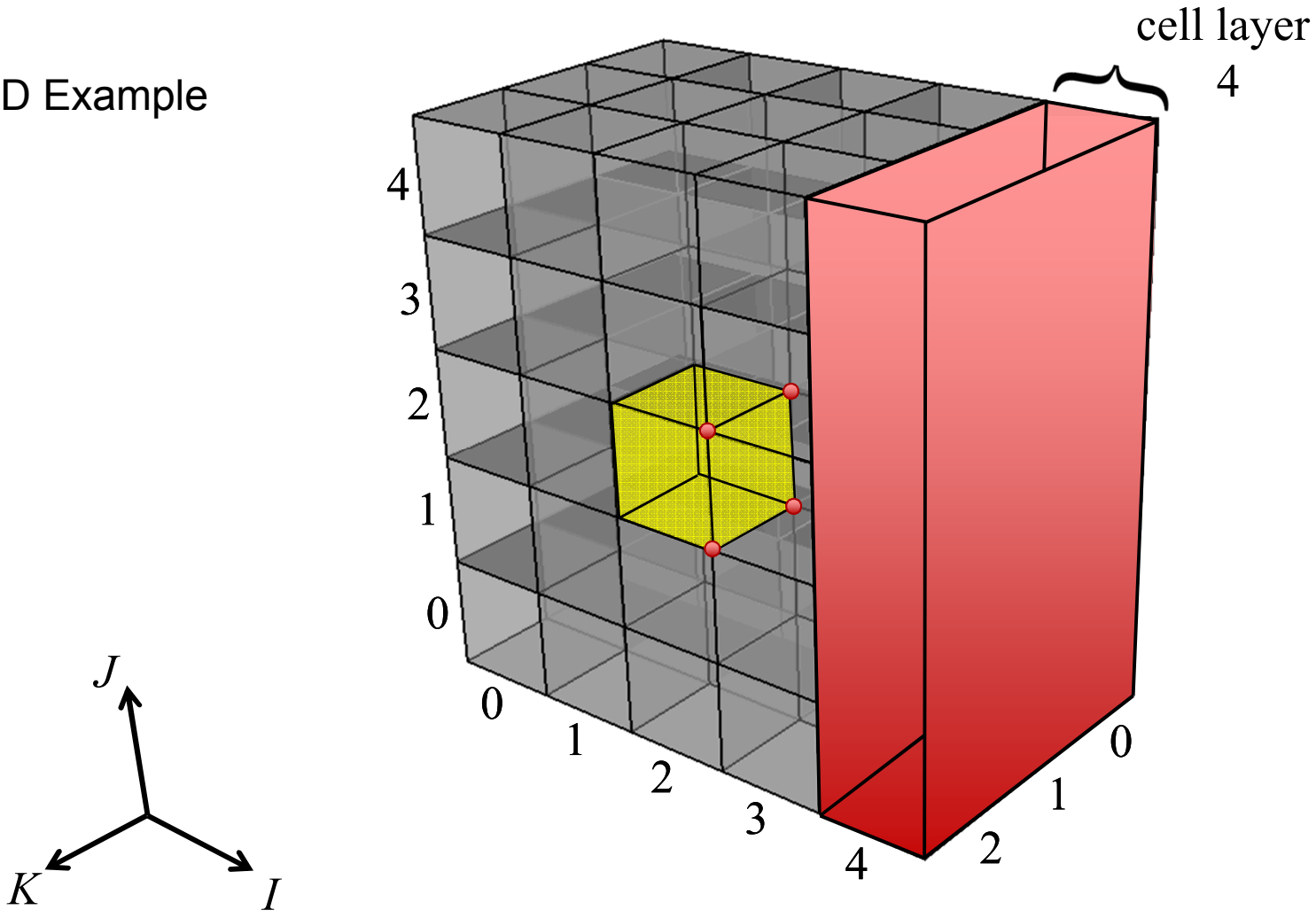
3D Example





2-Refinement Procedure

3D Example



3D Templates

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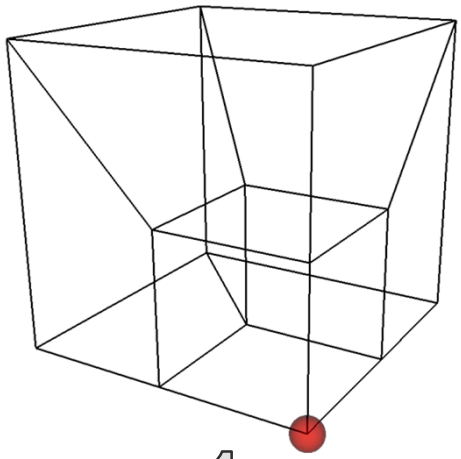

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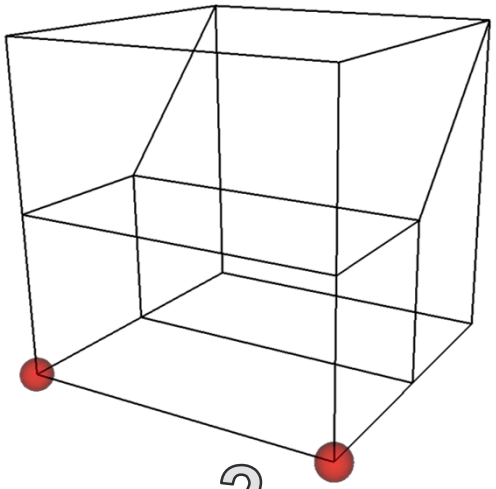

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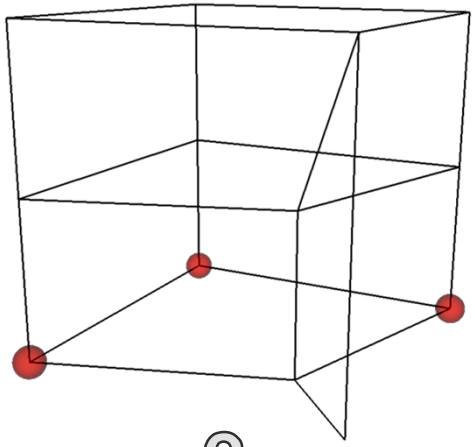

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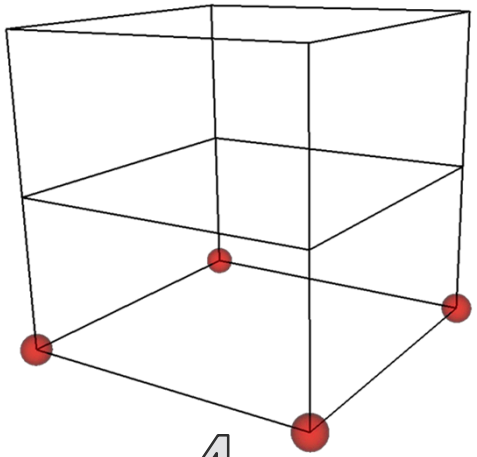

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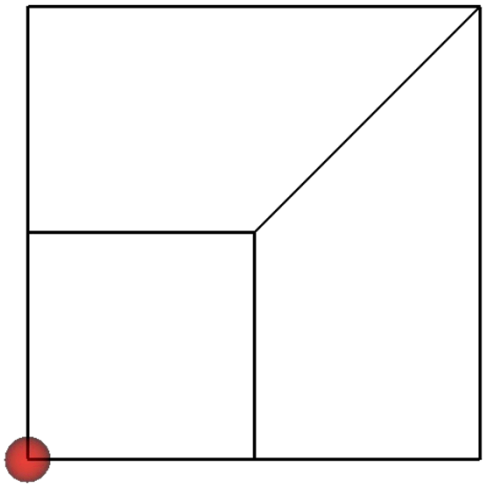
3D Face Templates



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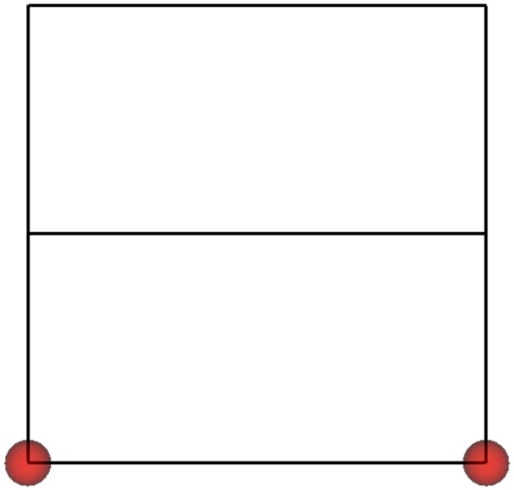

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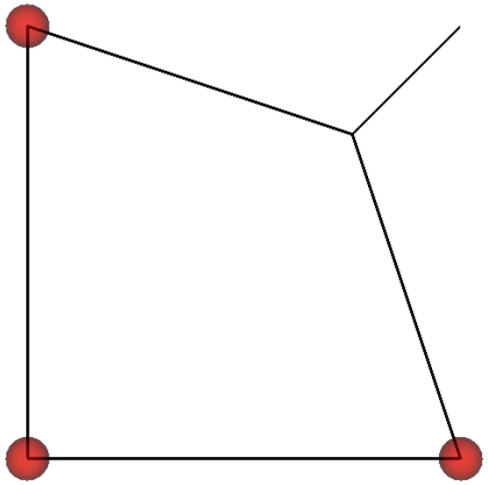

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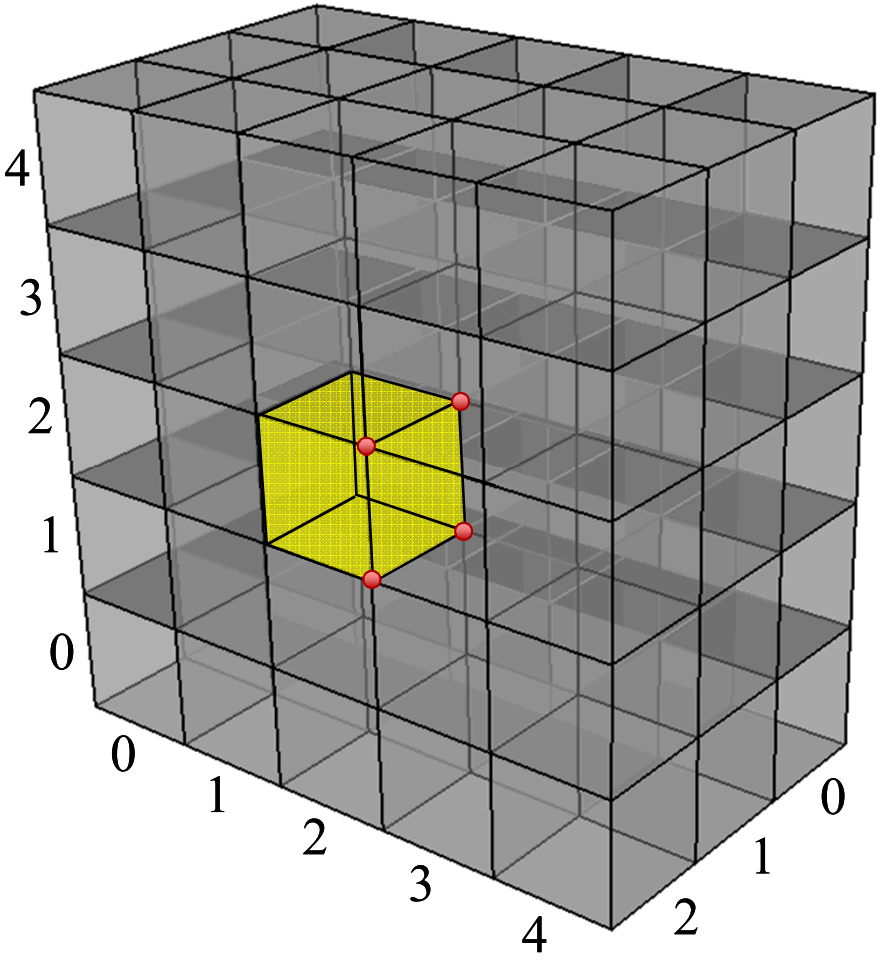
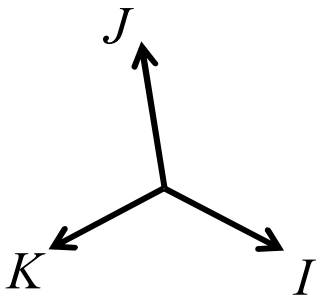
2-Refinement Procedure

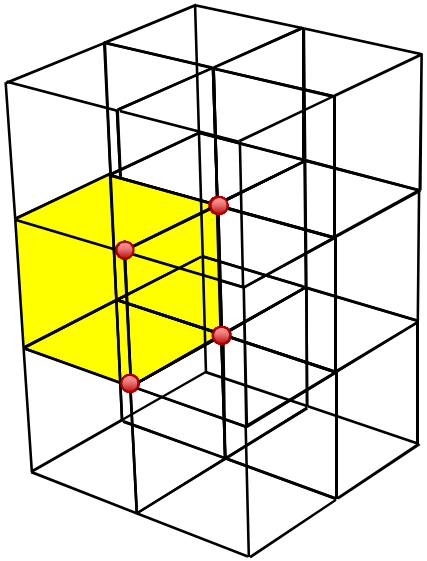
3D Example

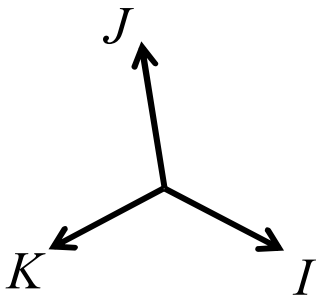




2-Refinement Procedure

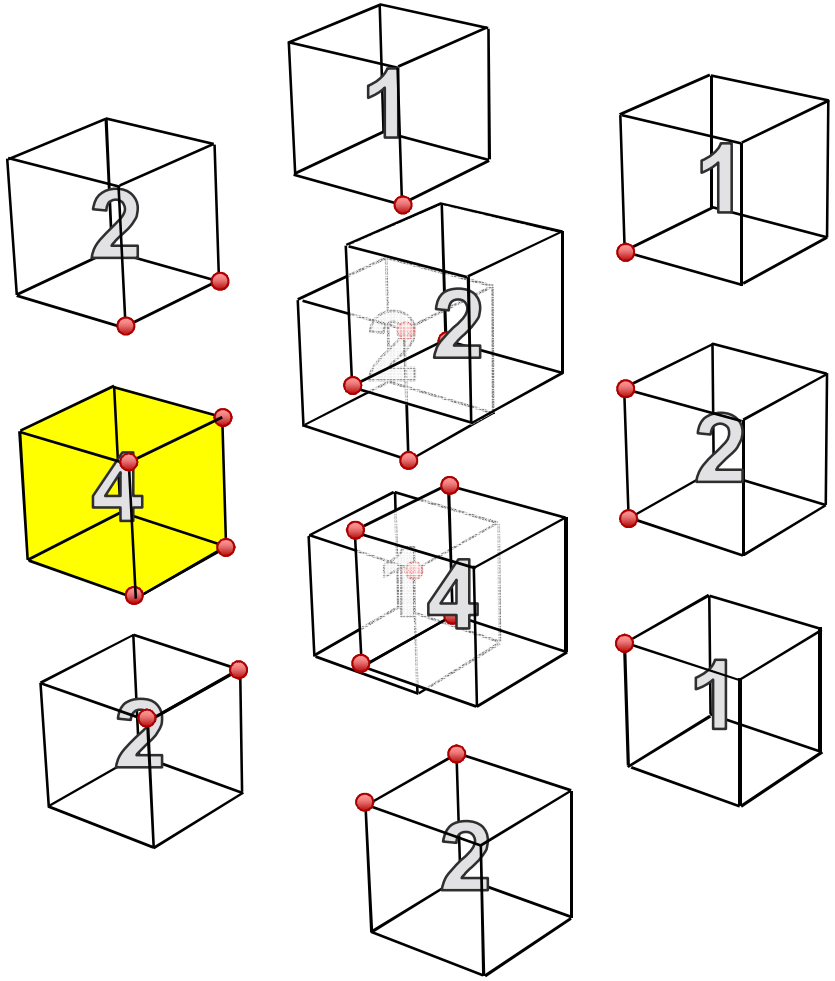
3D Example

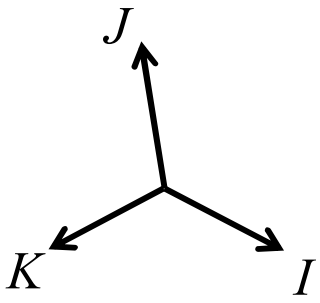




2-Refinement Procedure

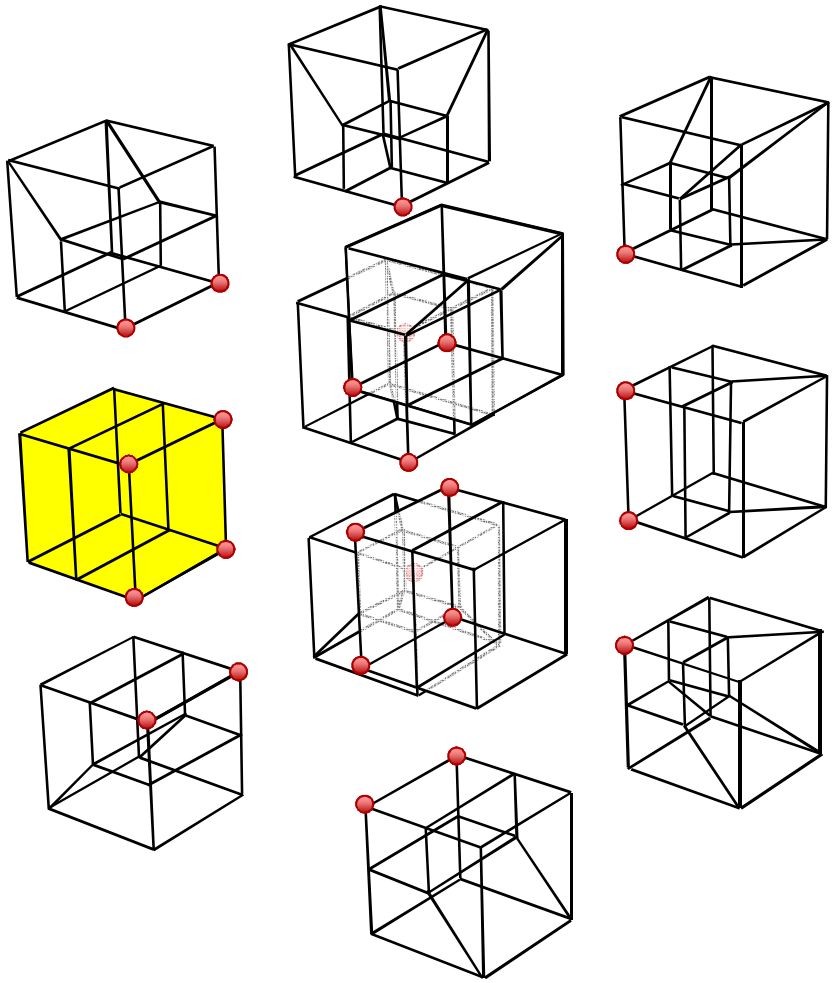
3D Example

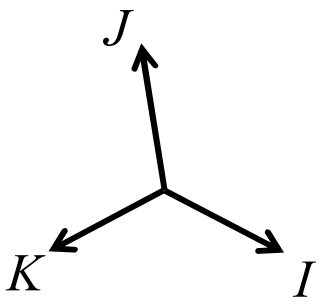




2-Refinement Procedure

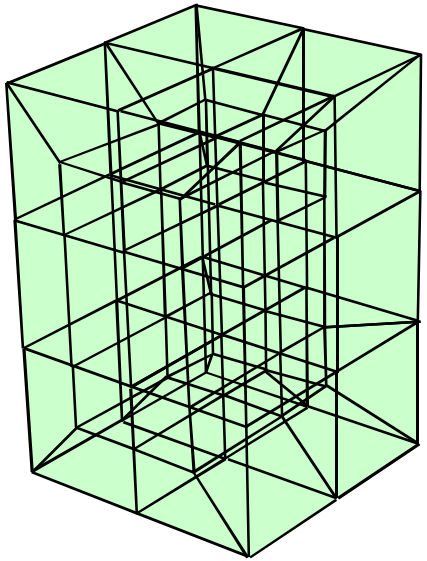
3D Example

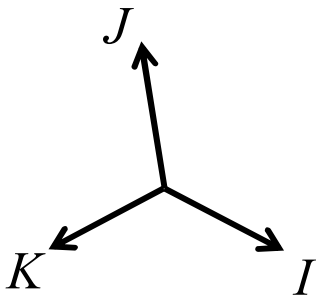




2-Refinement Procedure

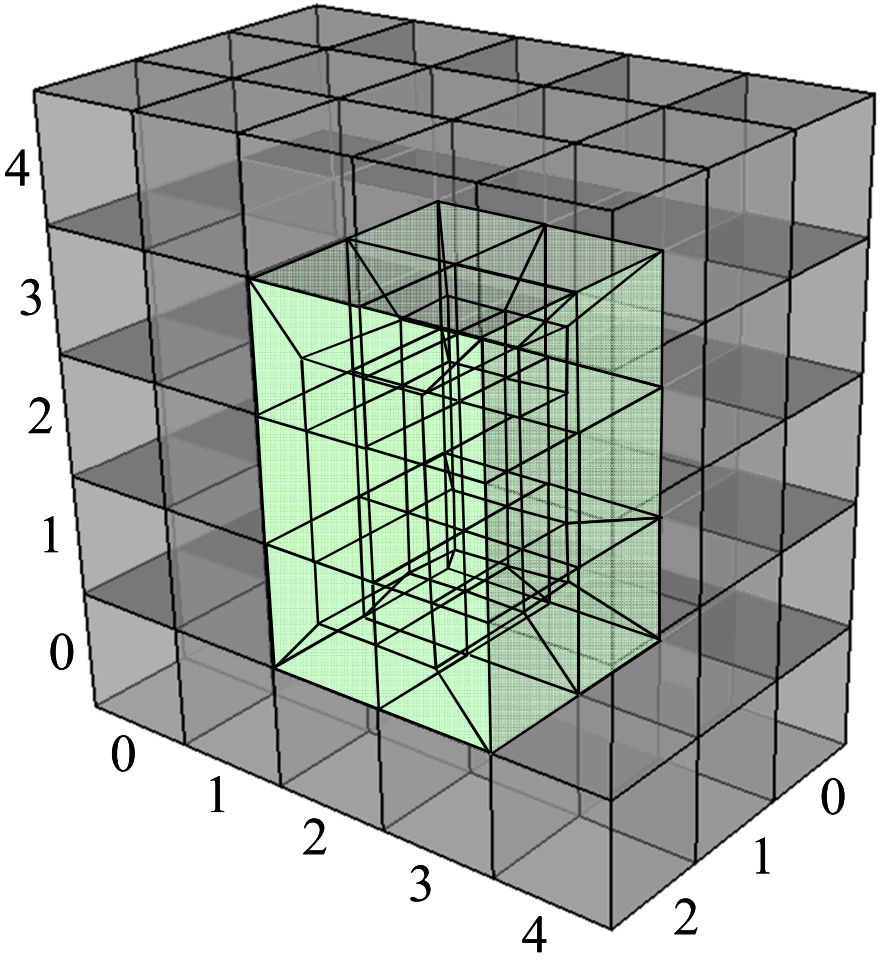
3D Example

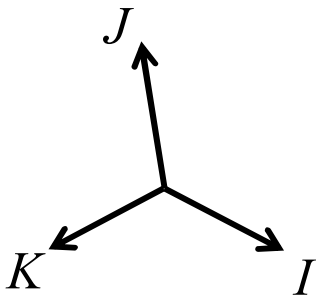




2-Refinement Procedure

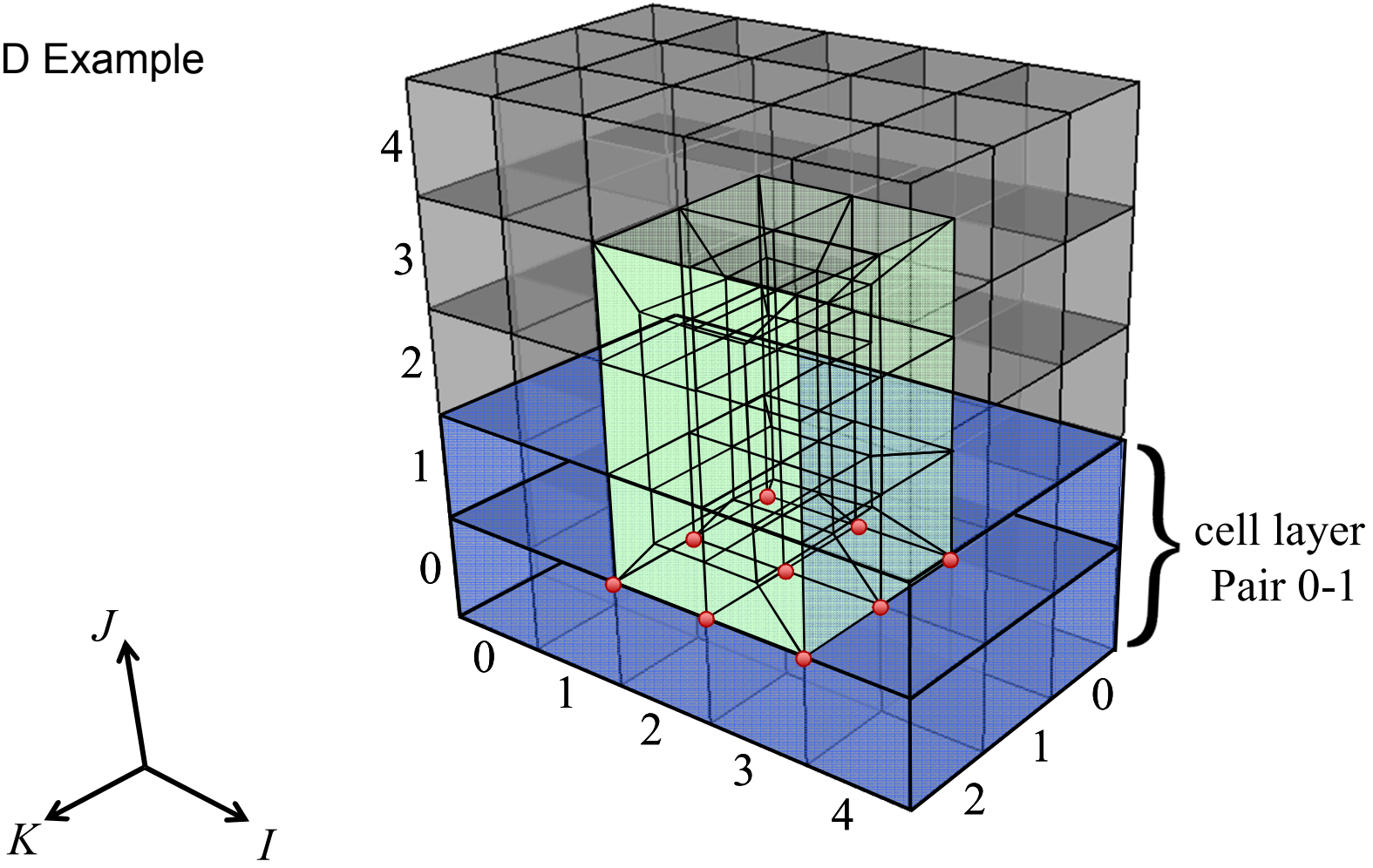
3D Example





2-Refinement Procedure

3D Example



2-Refinement Procedure

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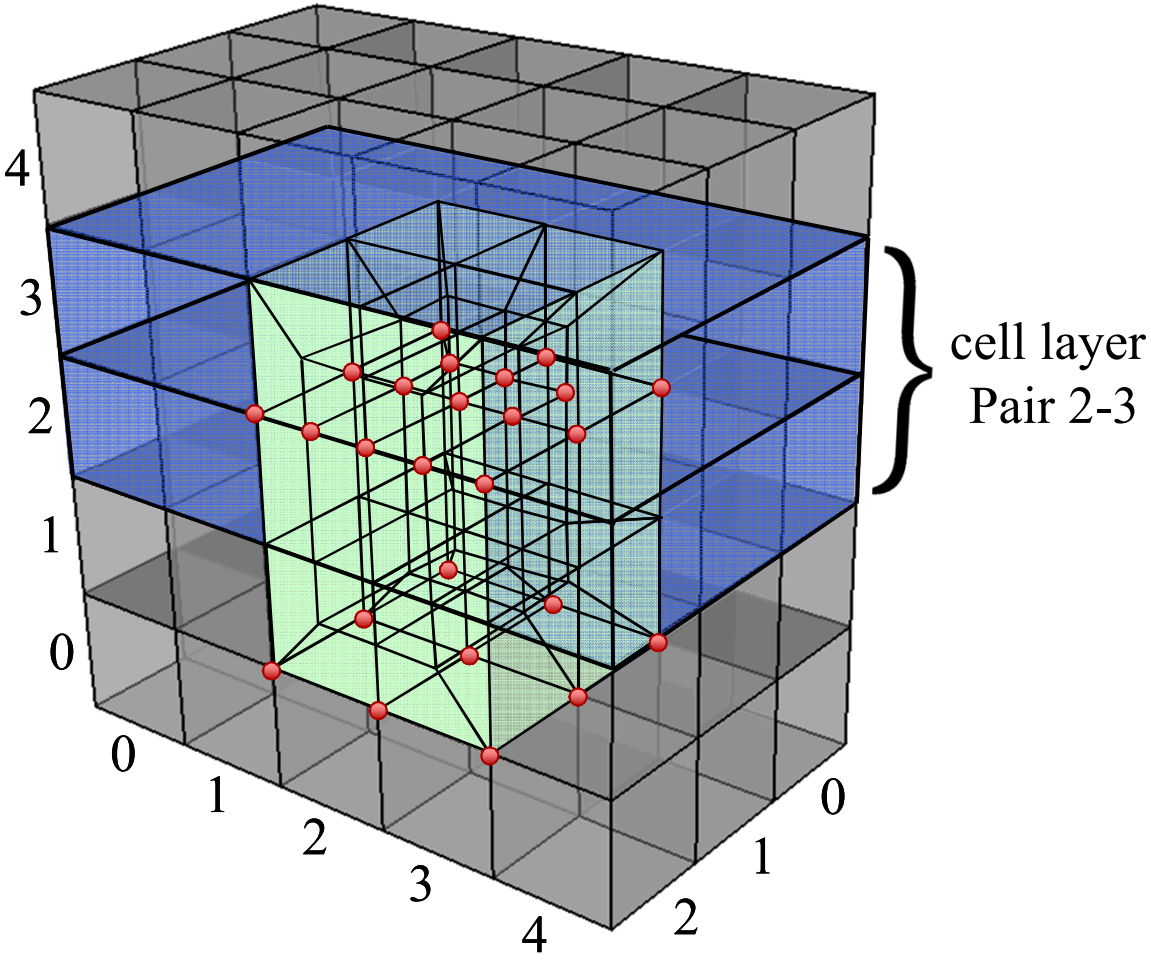
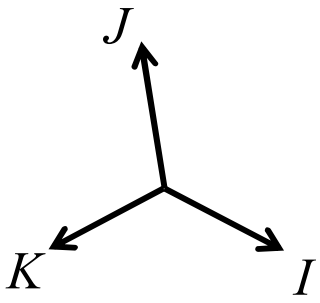
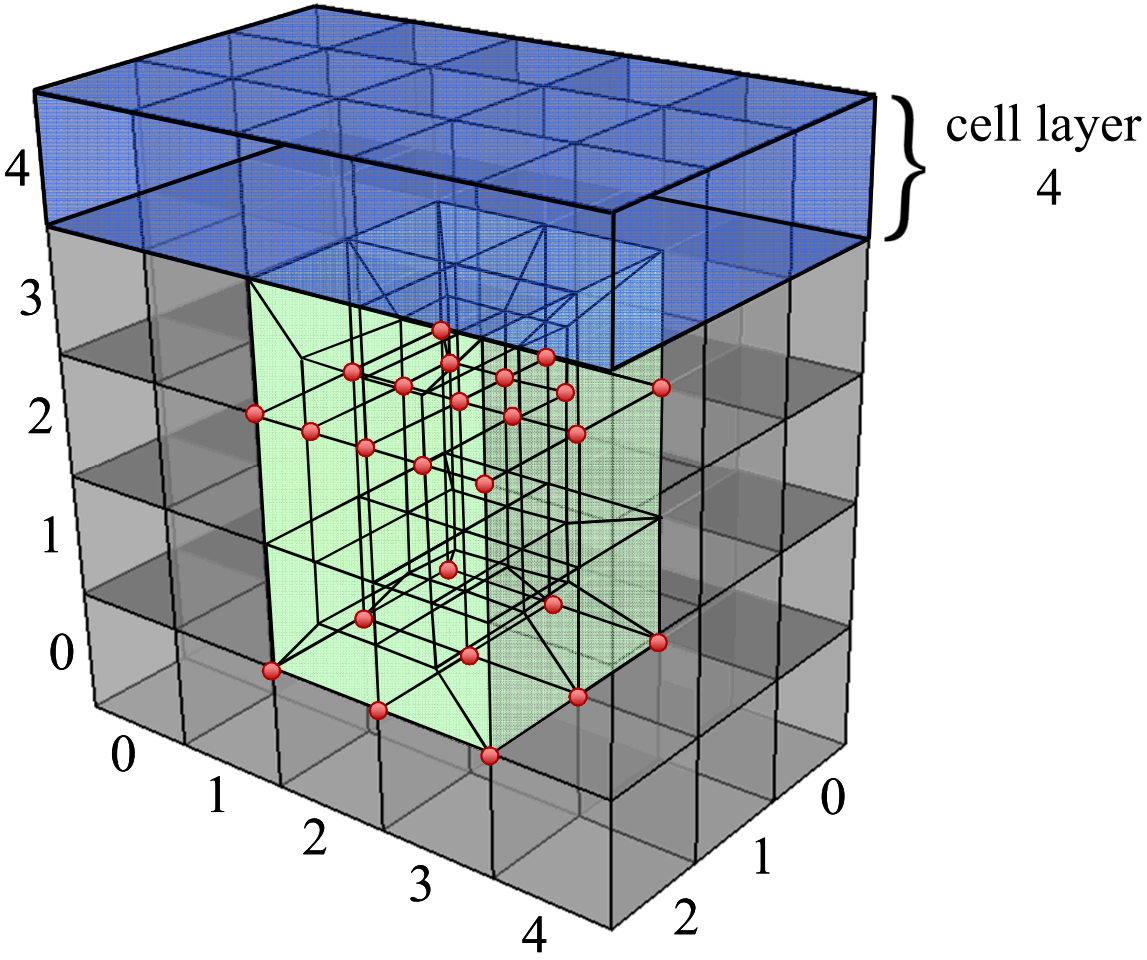
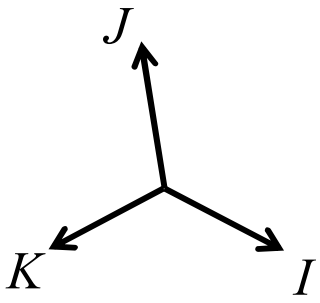




2-Refinement Procedure

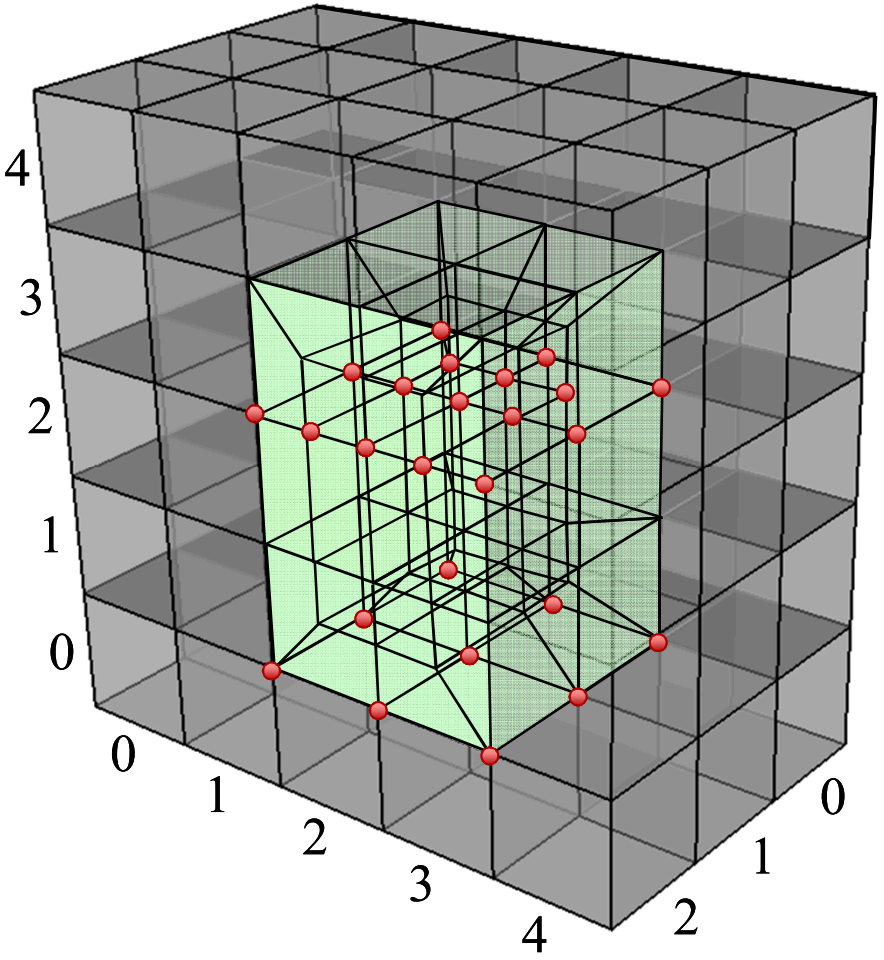
3D Example

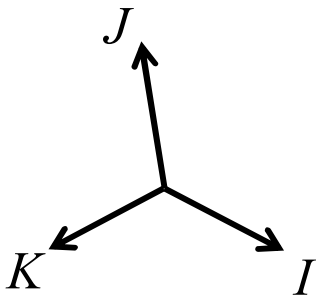




2-Refinement Procedure

3D Example





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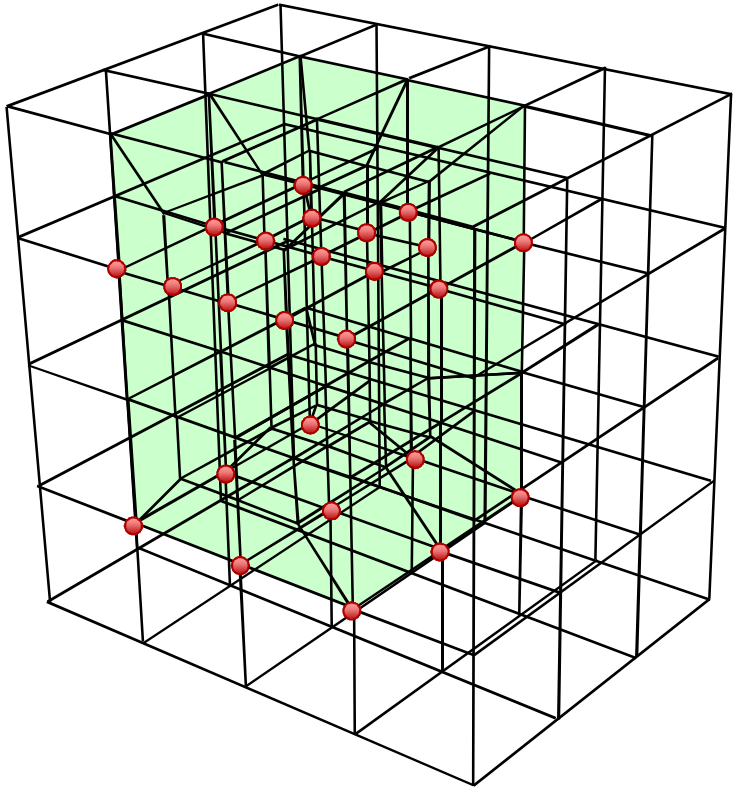
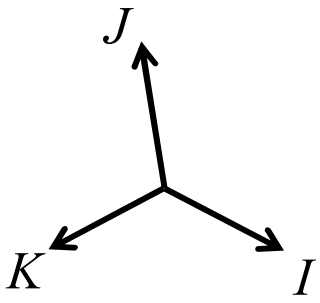
3D Example





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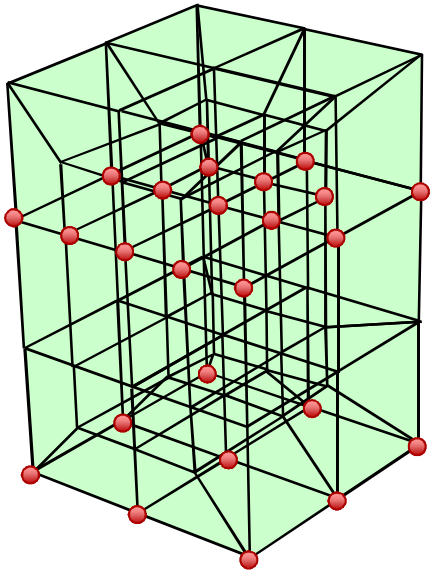
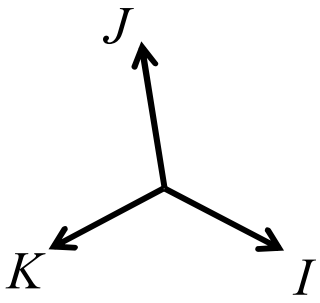
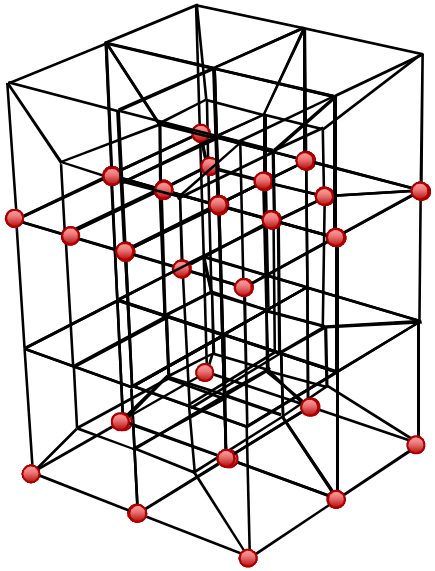
3D Example

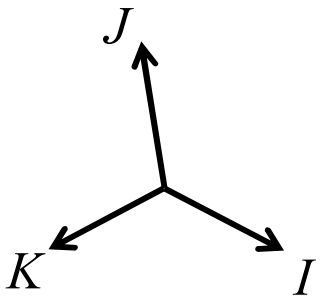




2-Refinement Procedure

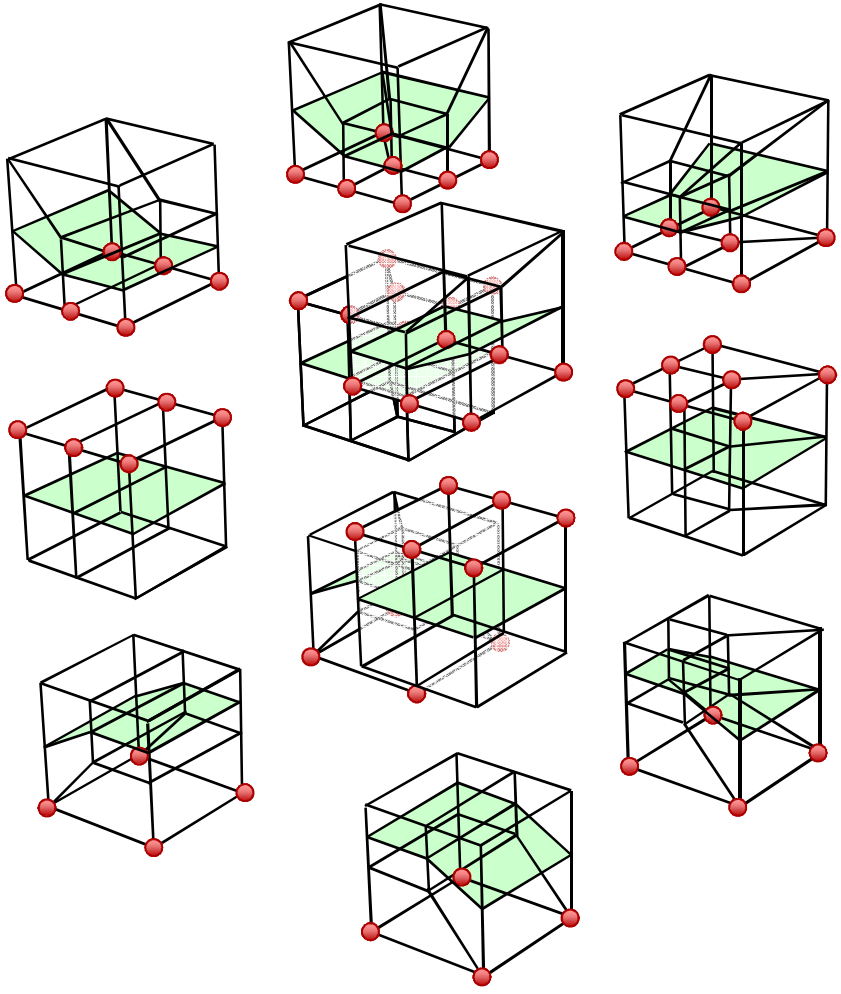
3D Example

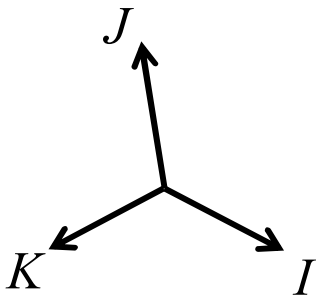




2-Refinement Procedure

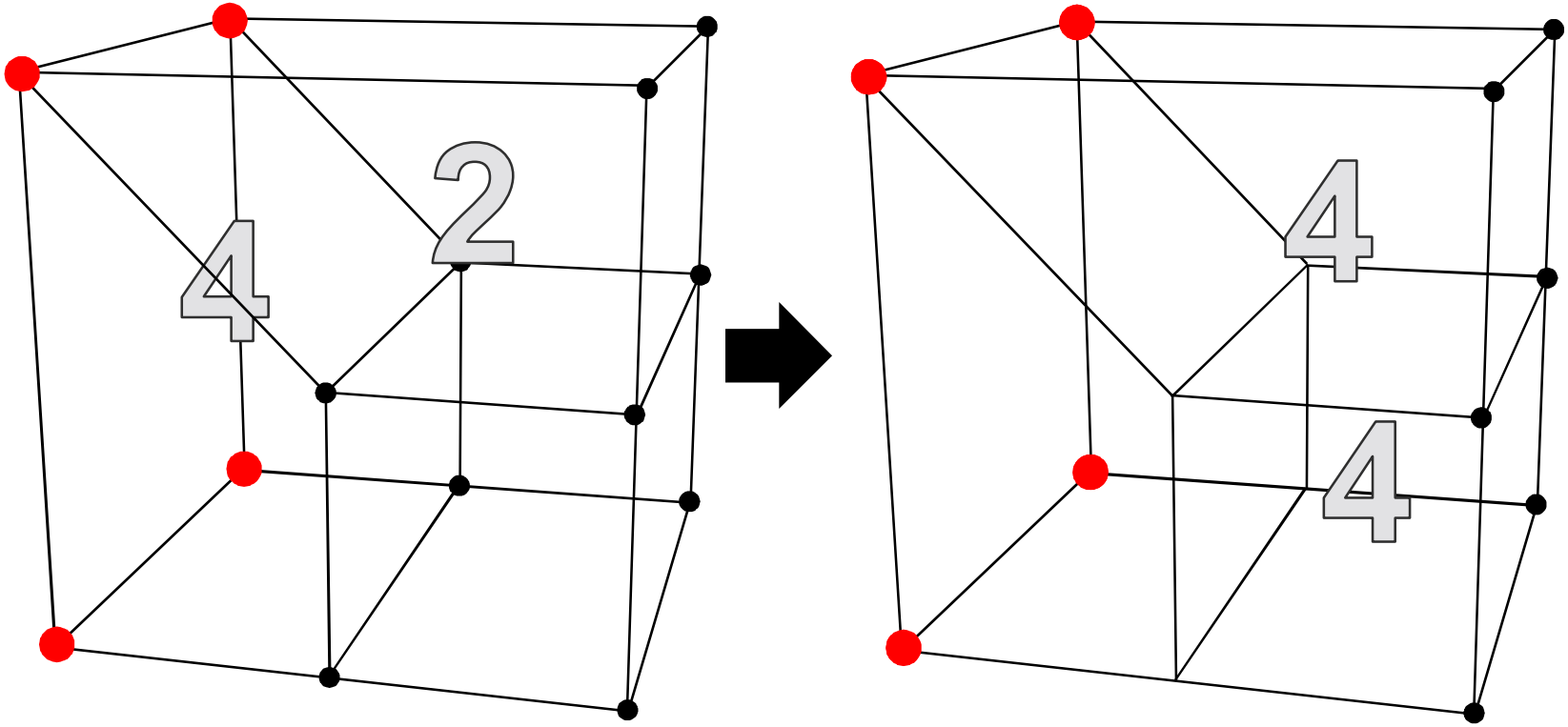
3D Example





Node Marking Propagation

3D Example



From Refined *2-Template*

Node Marking Propagation

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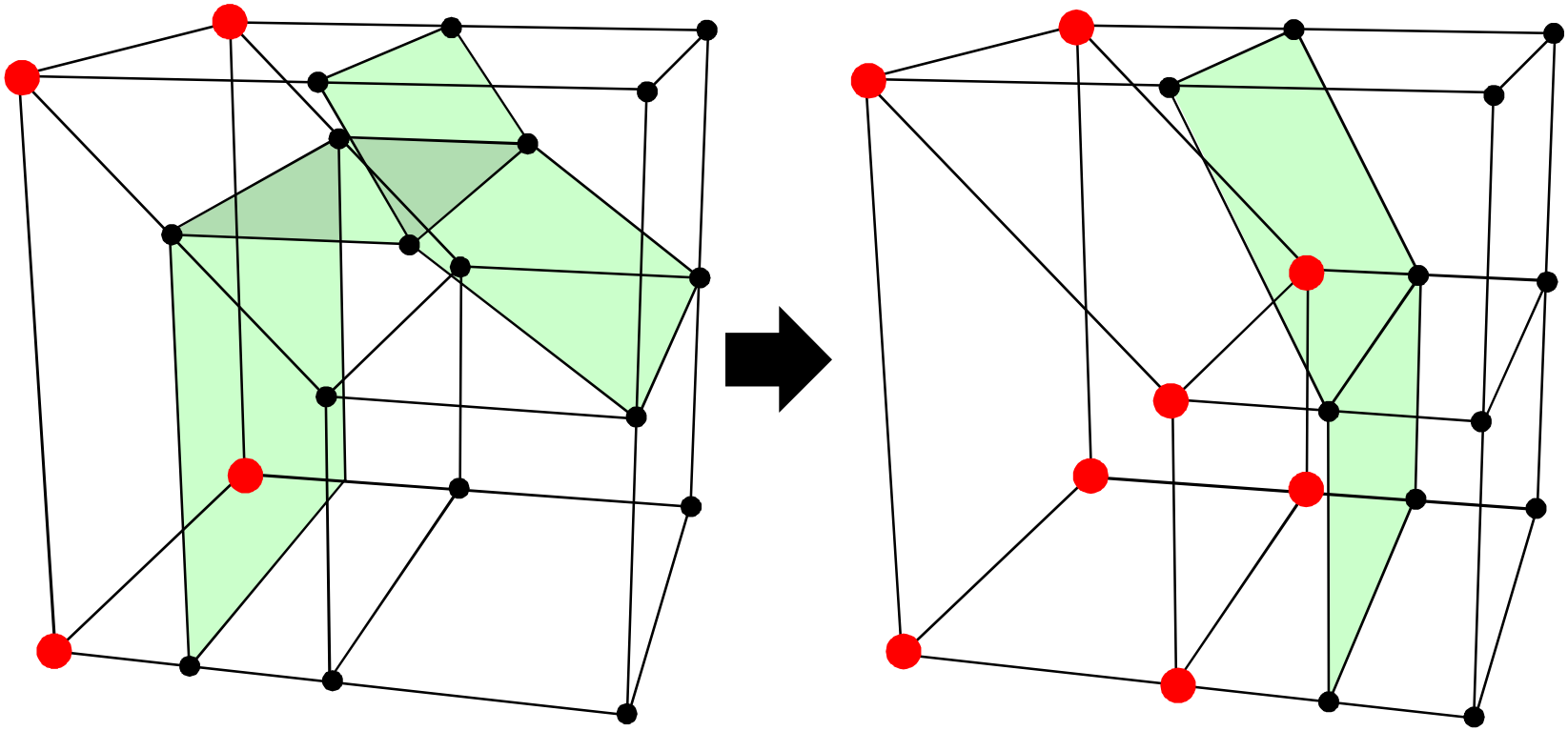
3D Example



From Refined *2-Template*

Node Marking Propagation

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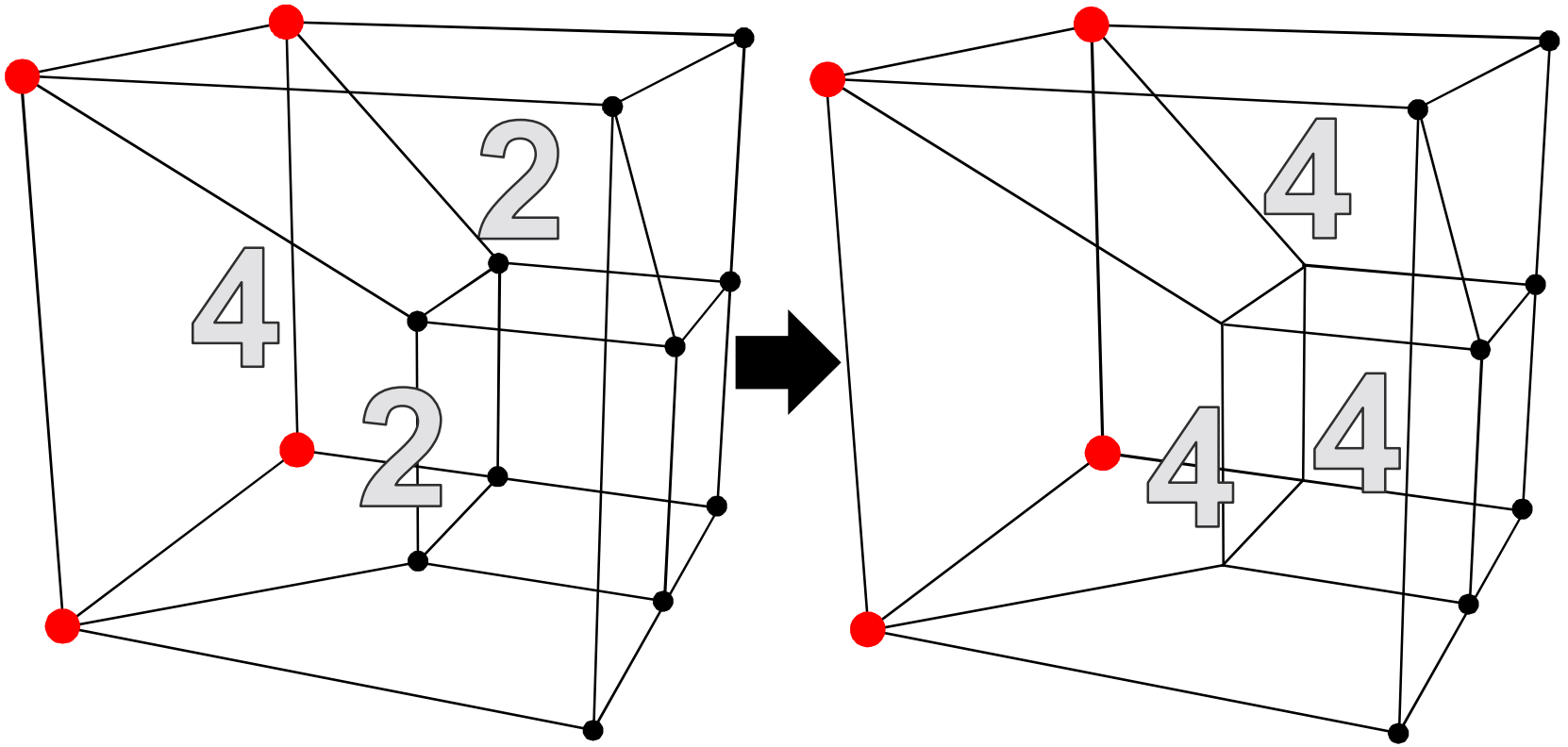

From Refined *1-Template*

Node Marking Propagation

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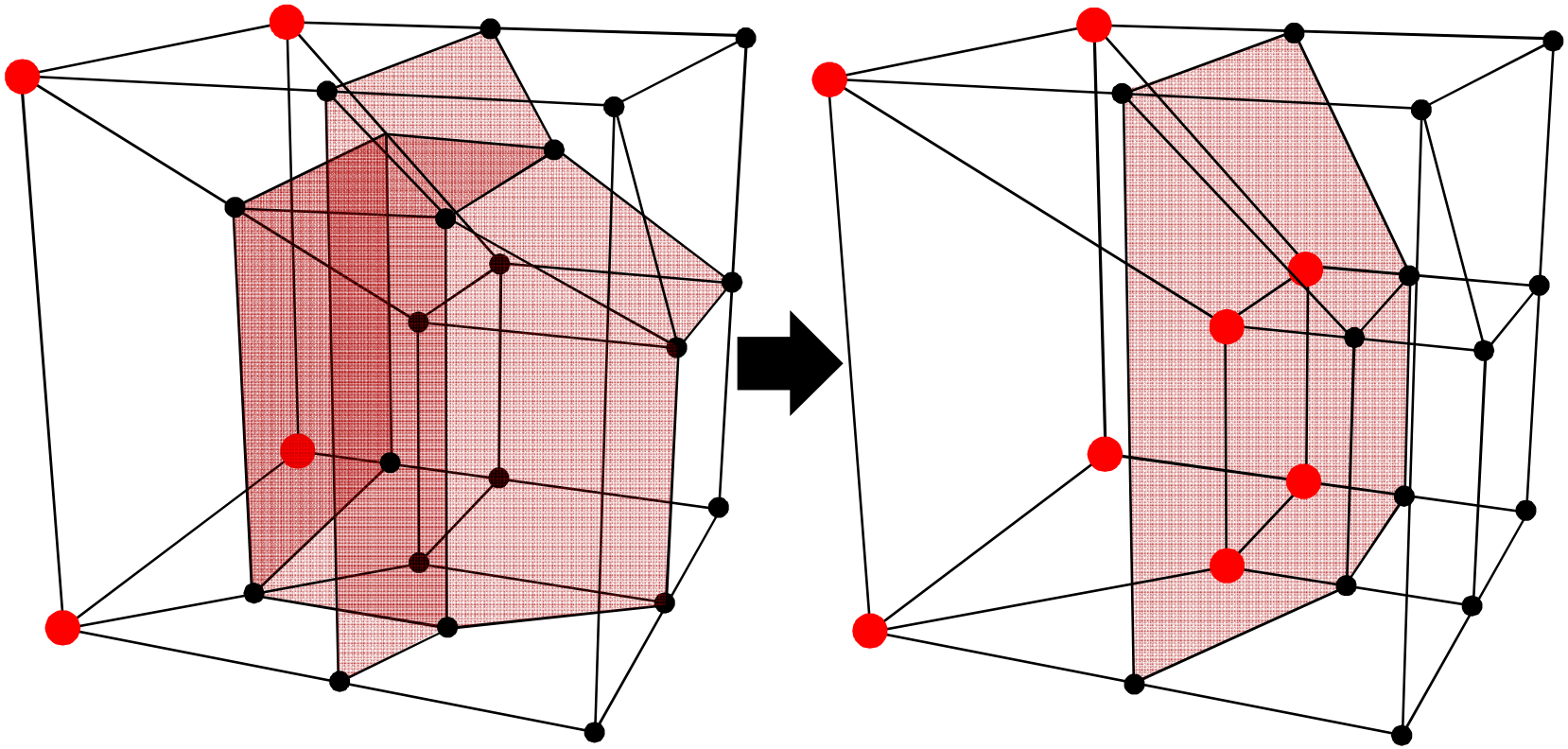
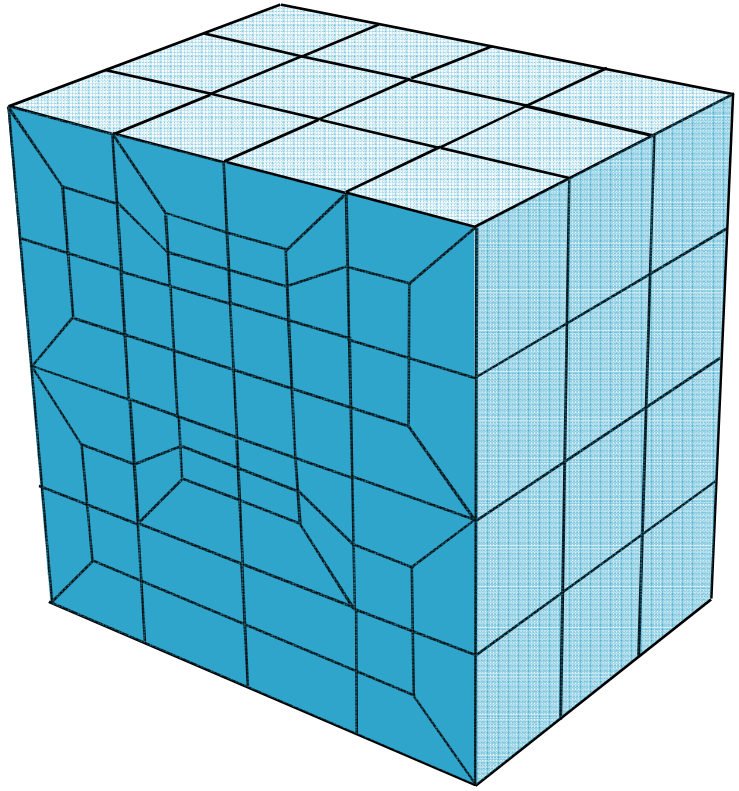
3D Example

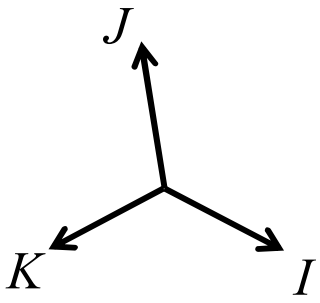


From Refined *1-Template*

2-Refinement Procedure

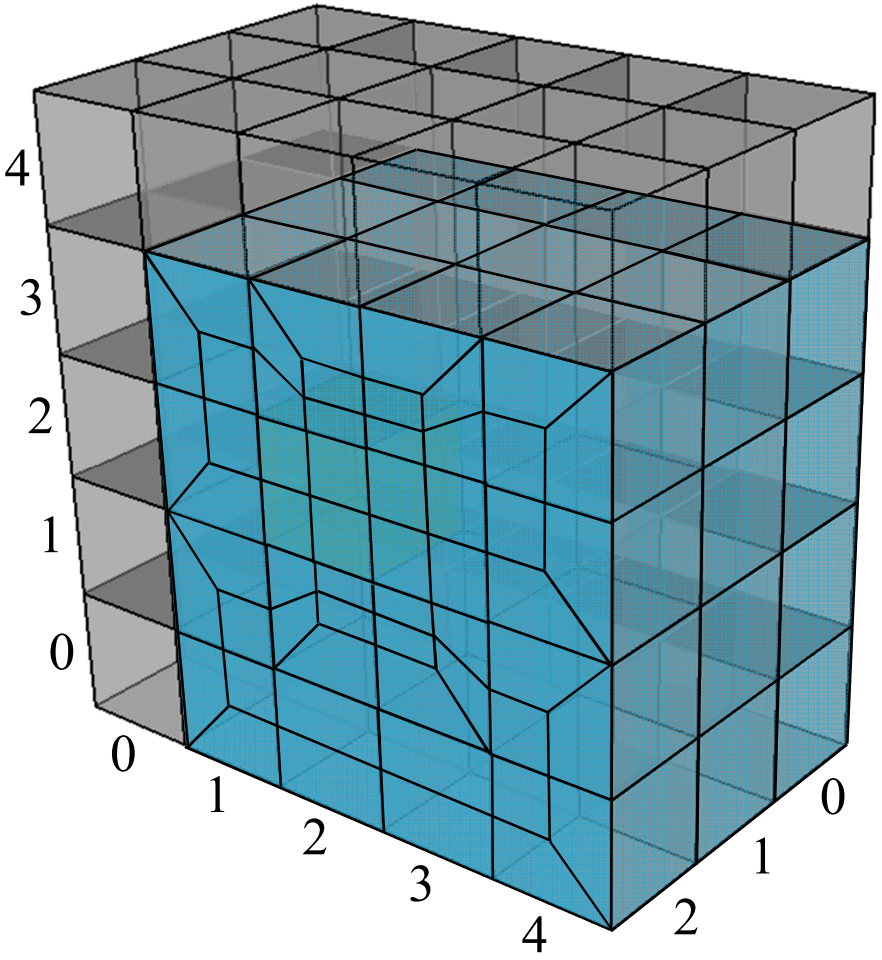
3D Example

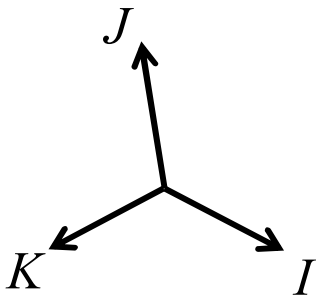




2-Refinement Procedure

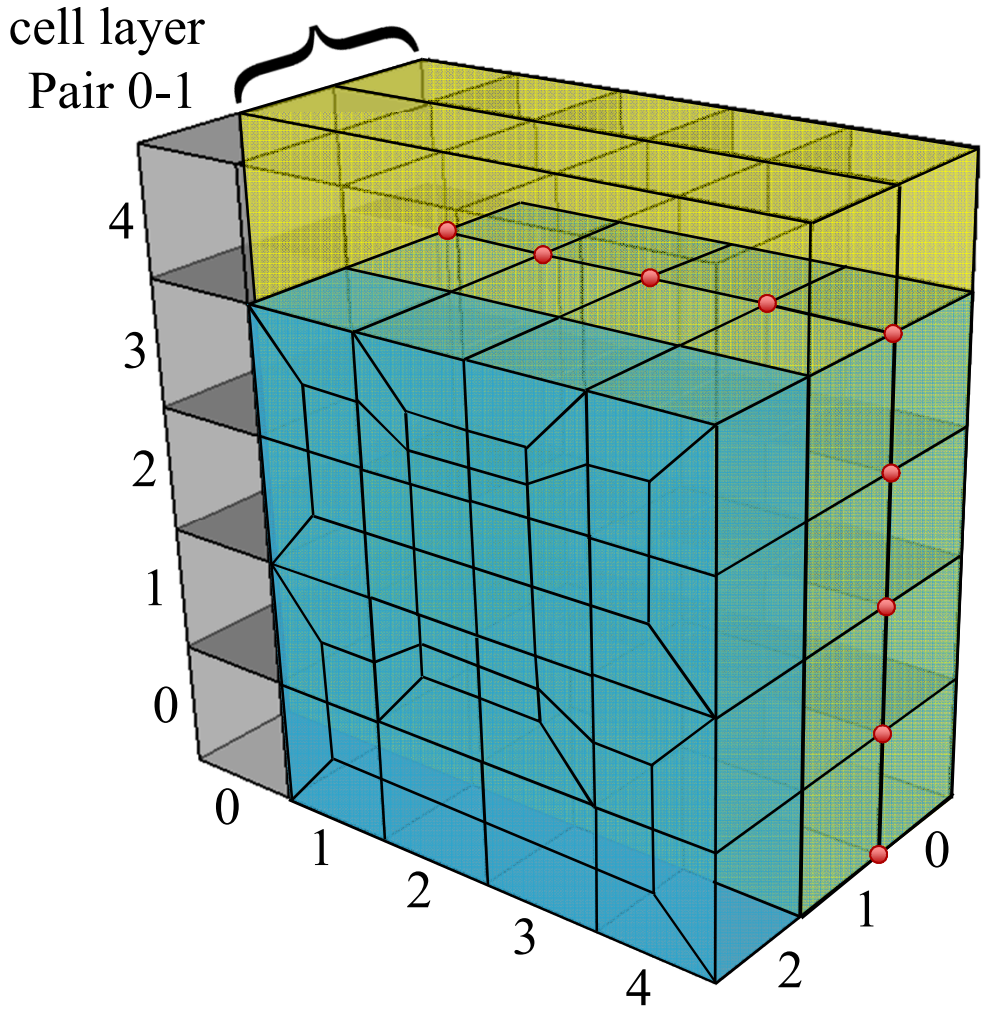
3D Example





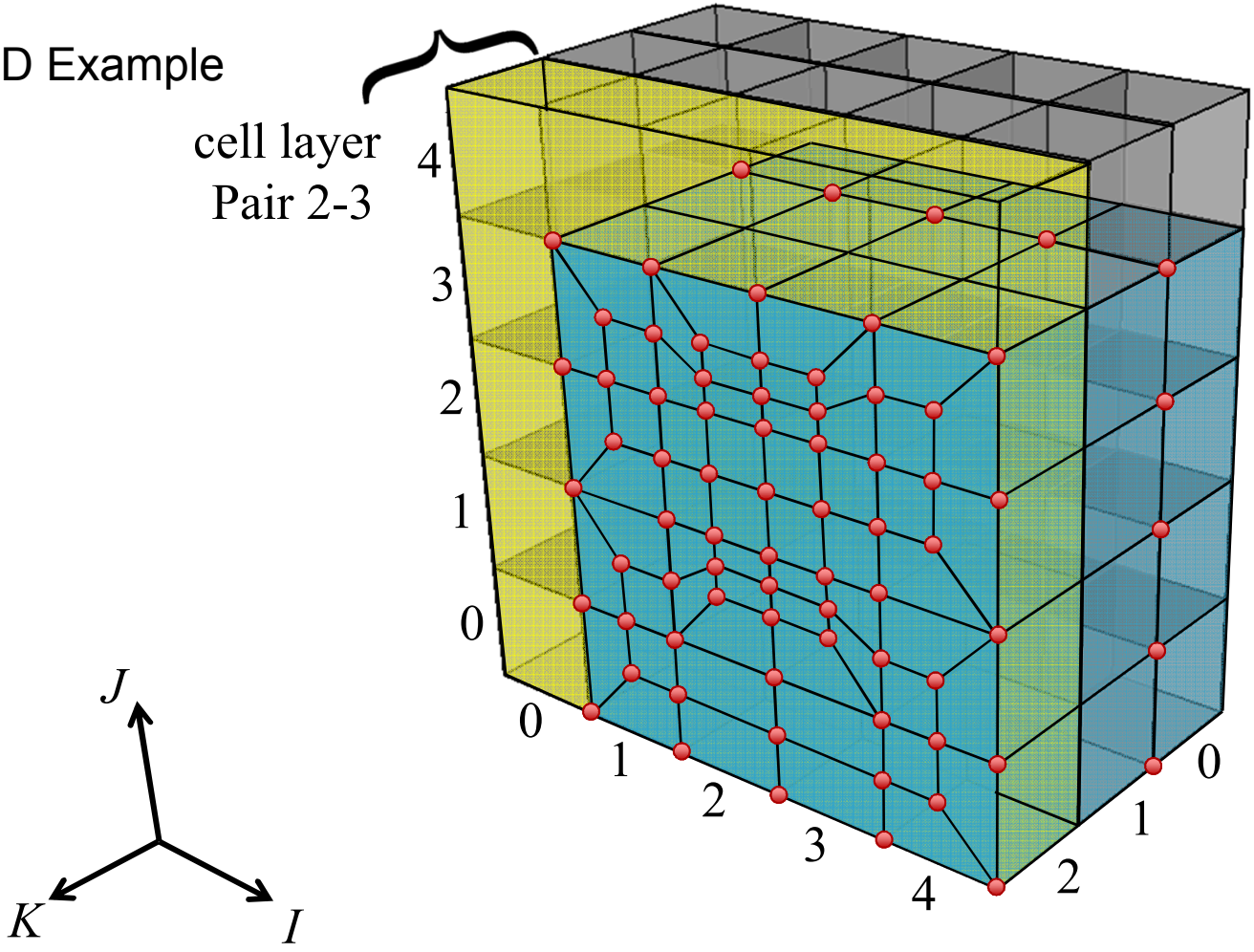
2-Refinement Procedure

3D Example



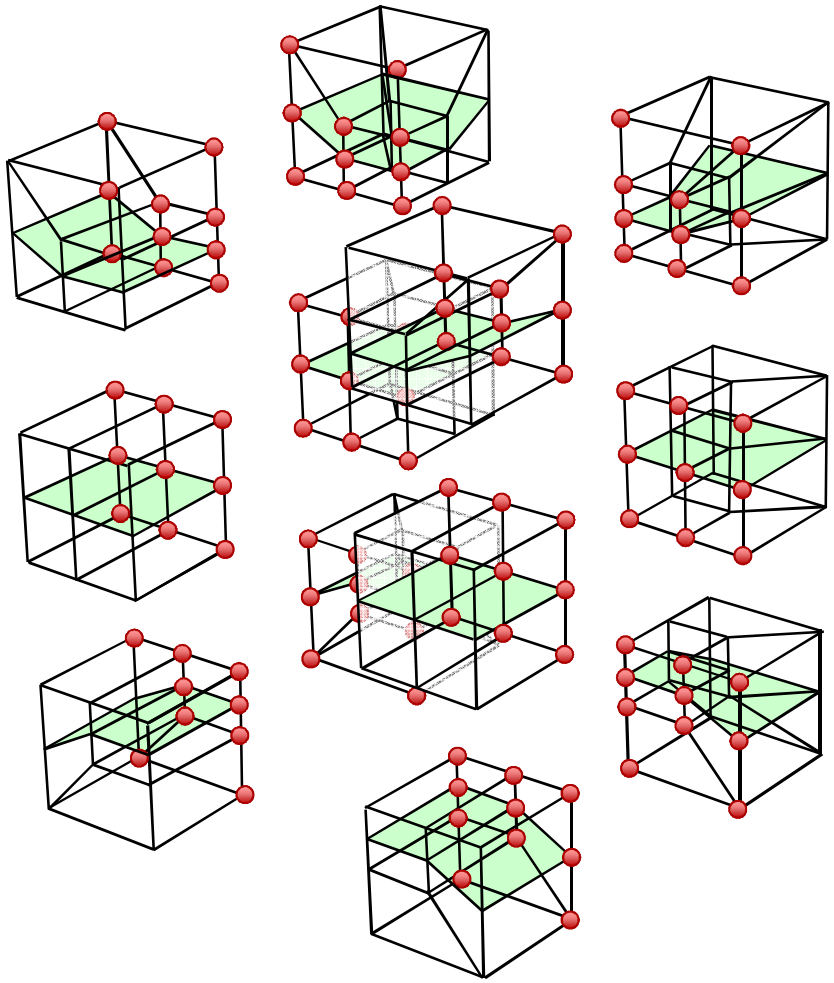
2-Refinement Procedure

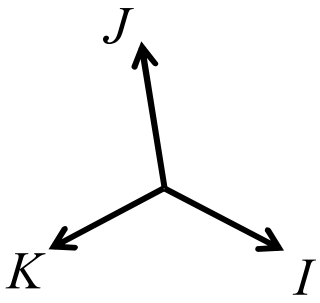
3D Example



2-Refinement Procedure

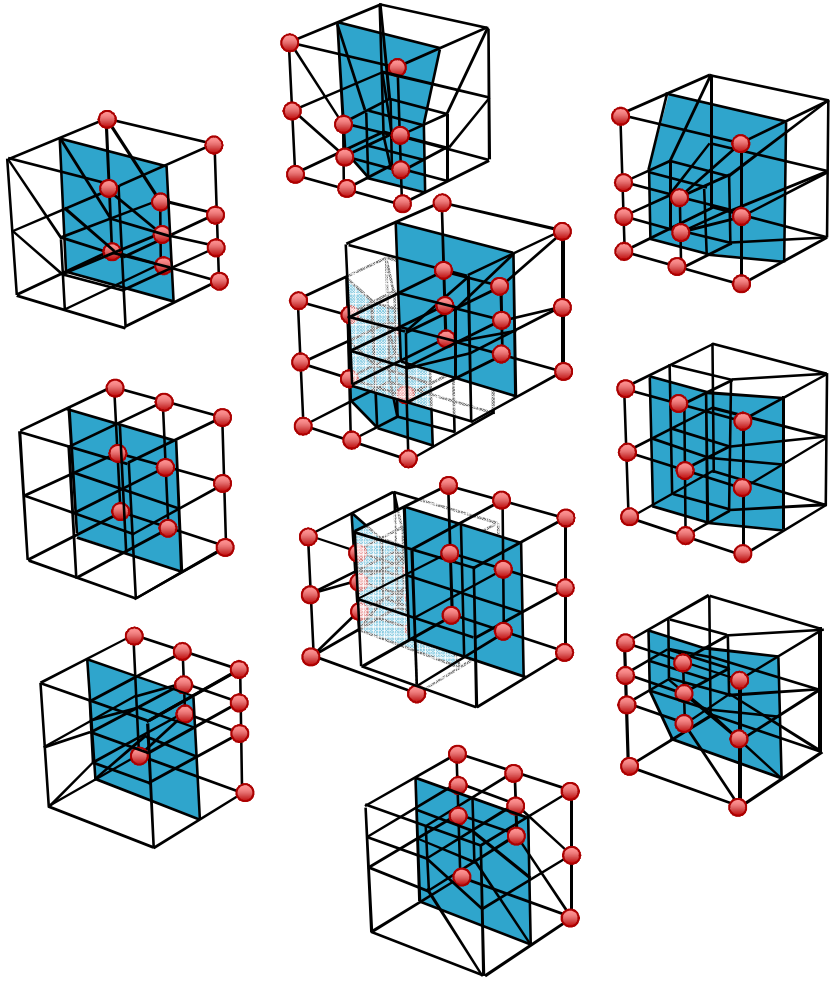
3D Example

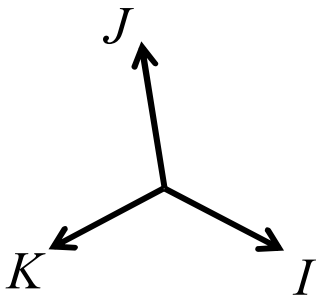




2-Refinement Procedure

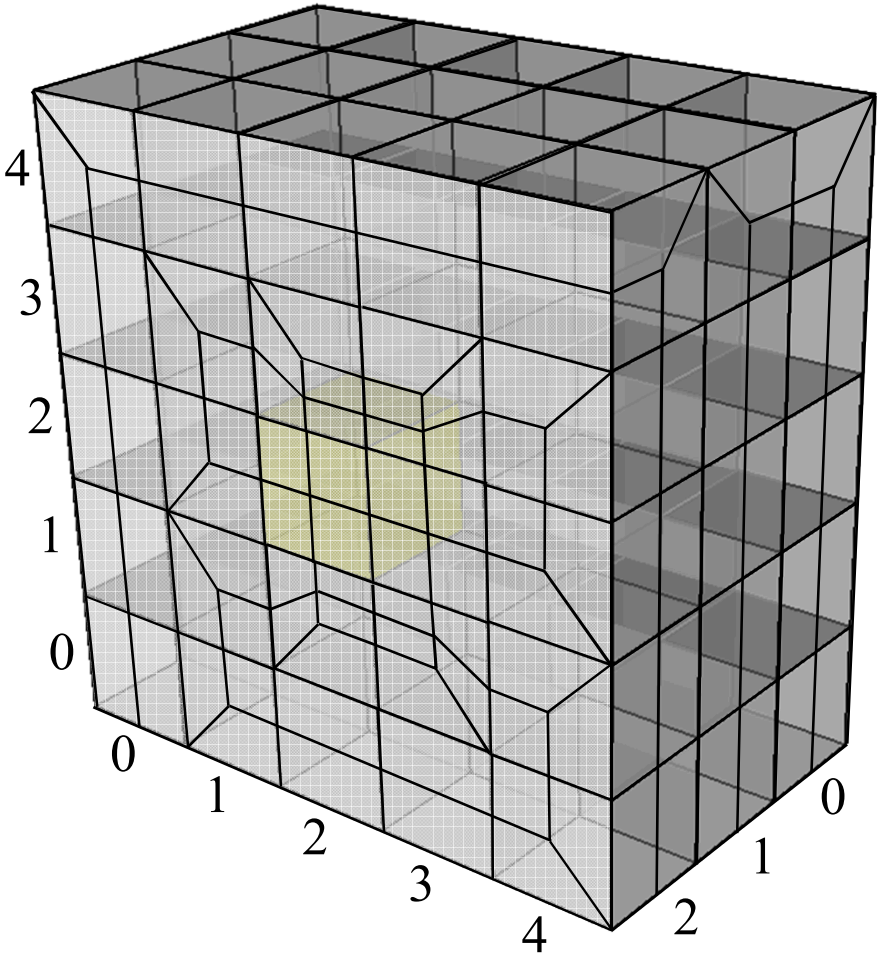
3D Example

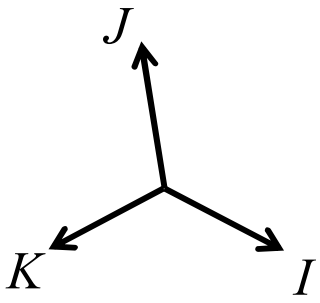




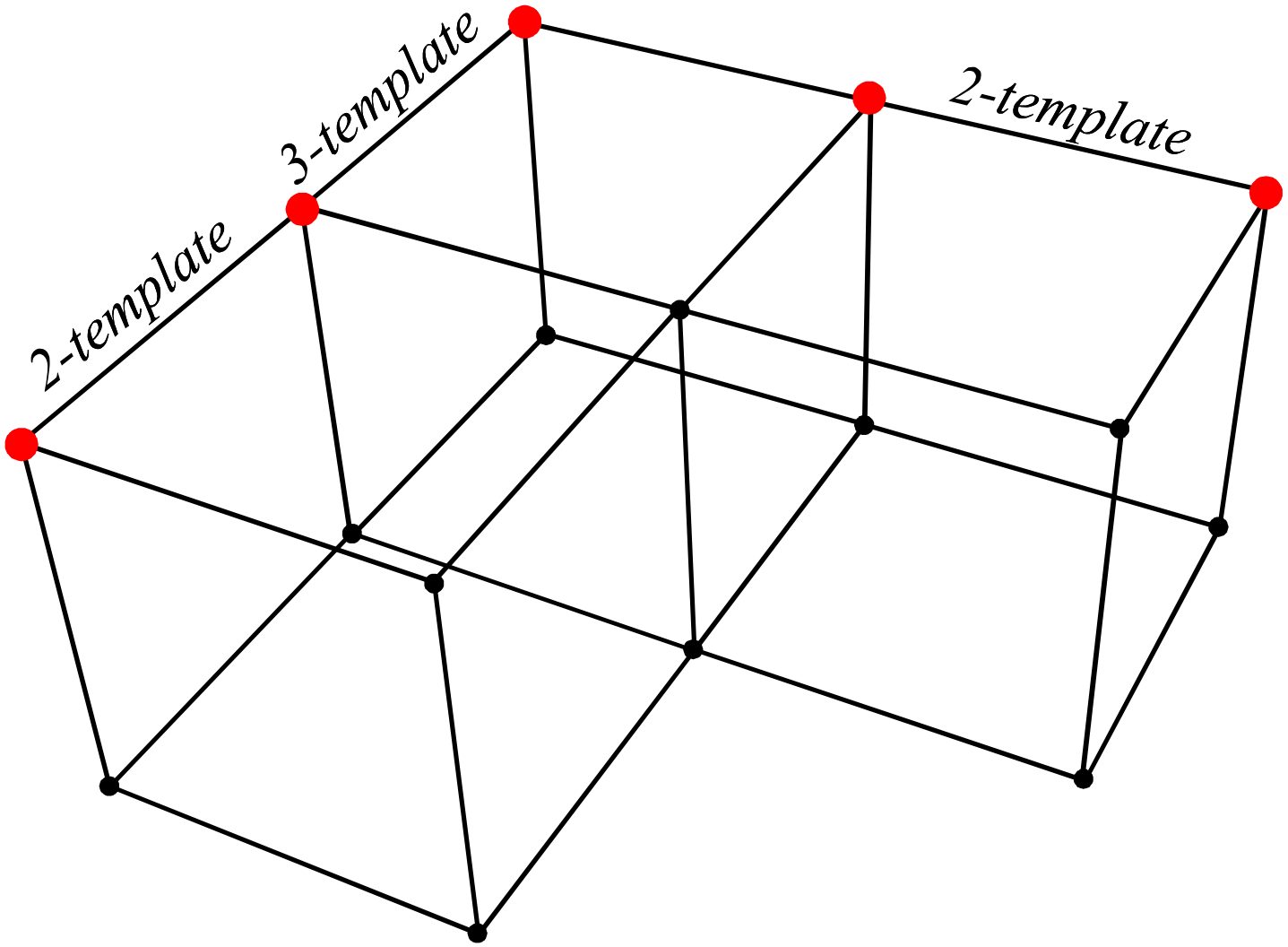
2-Refinement Procedure

3D Example





3-Template



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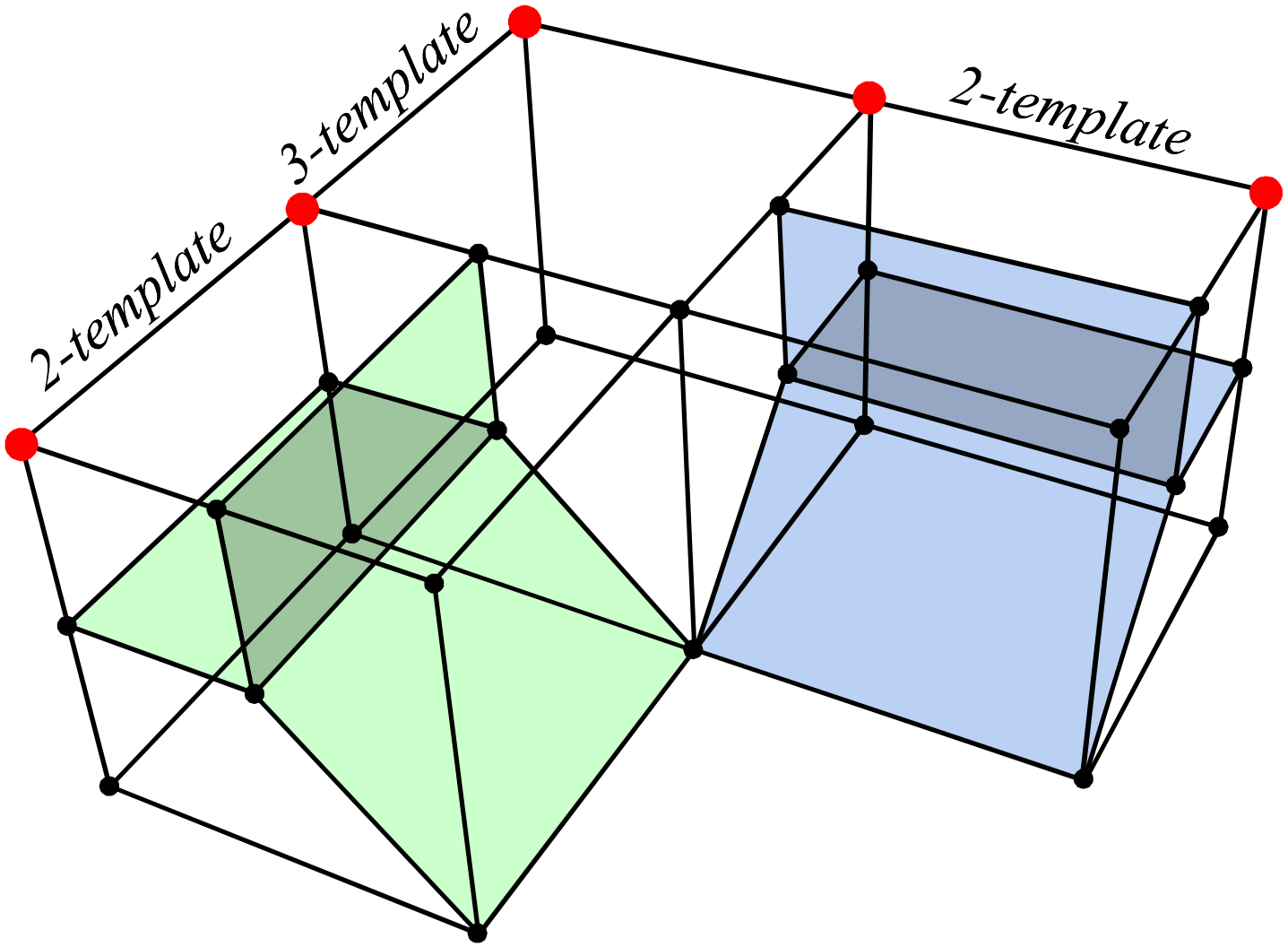

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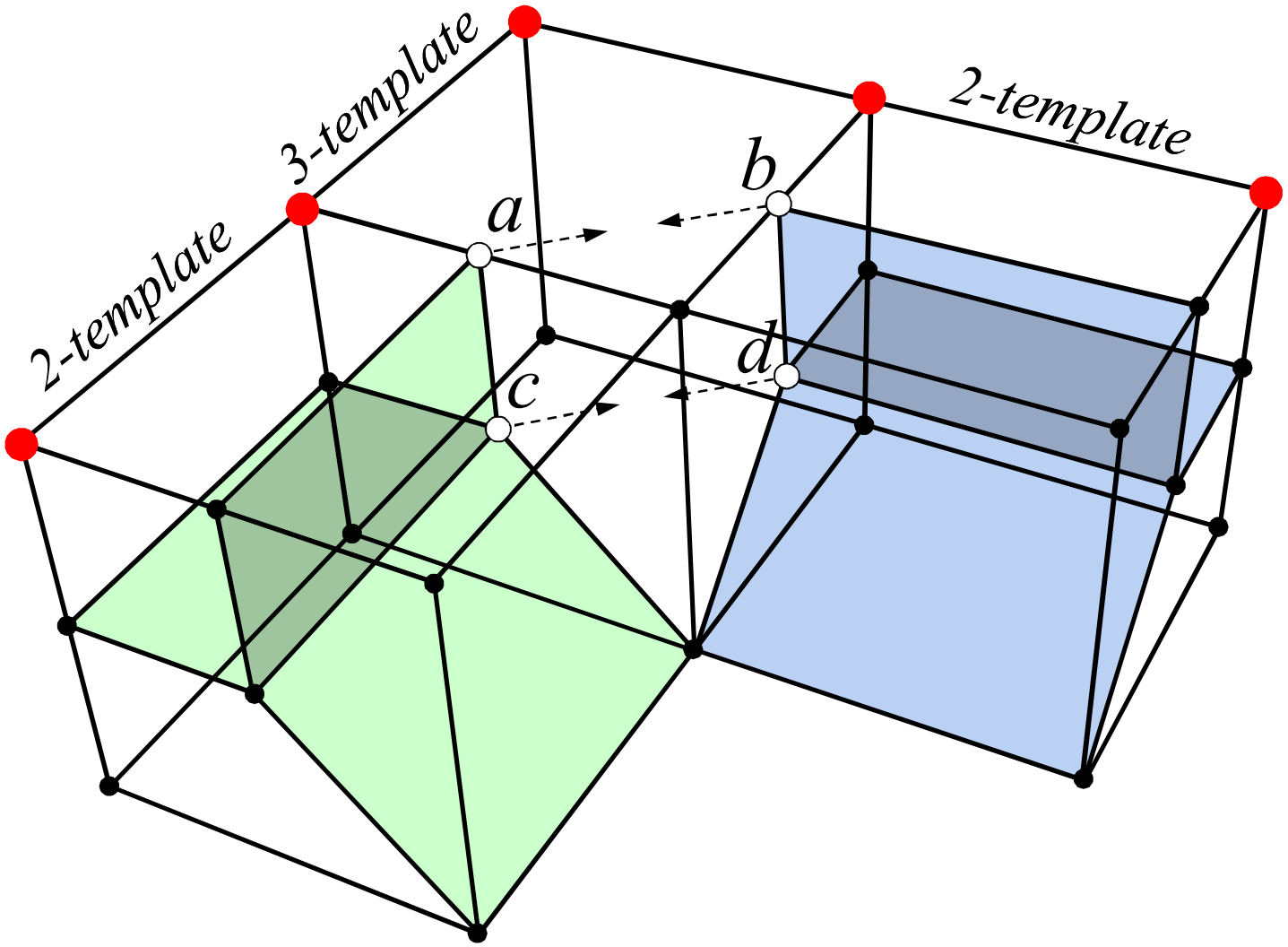

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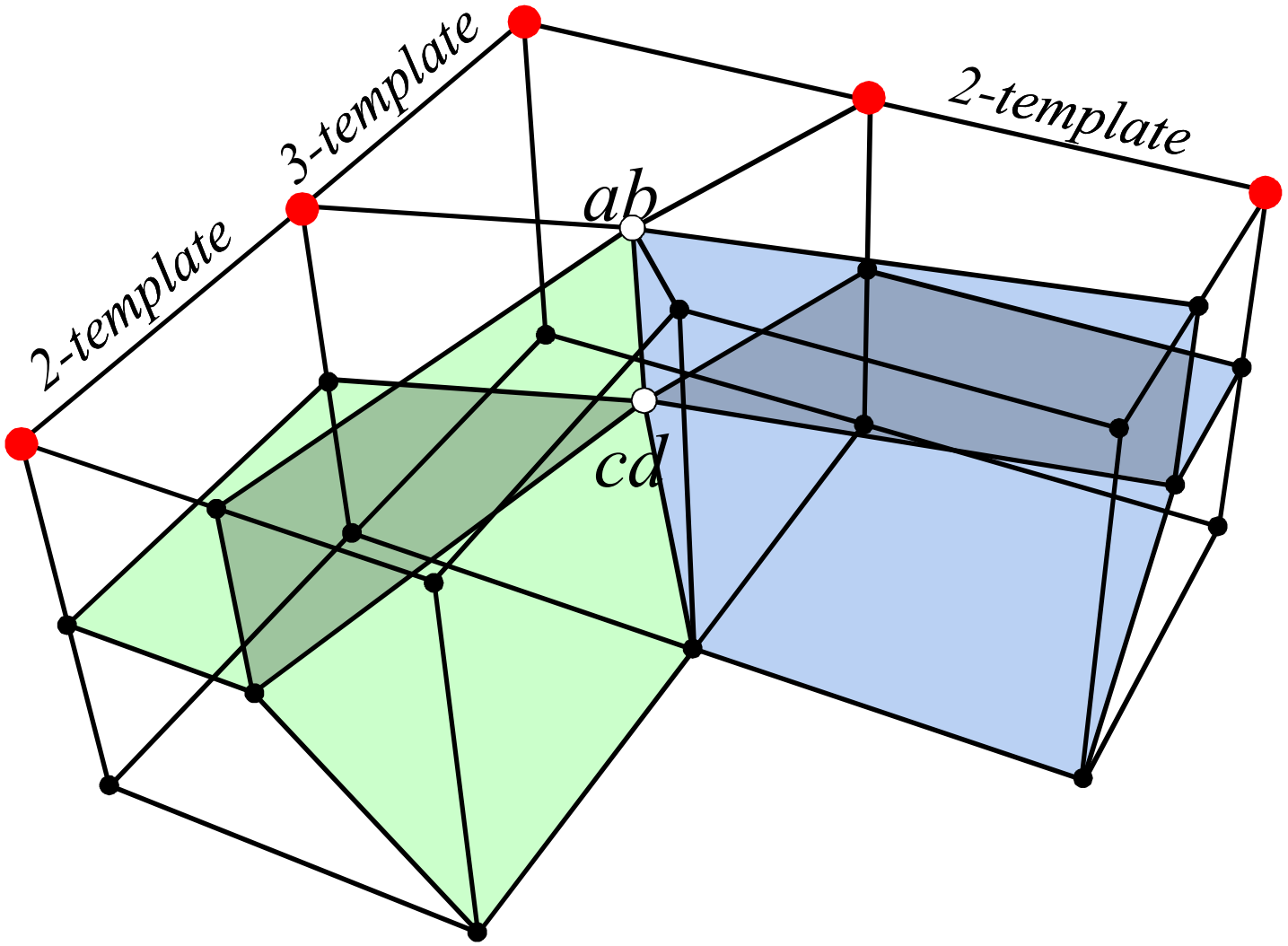

Multi-level Refinement

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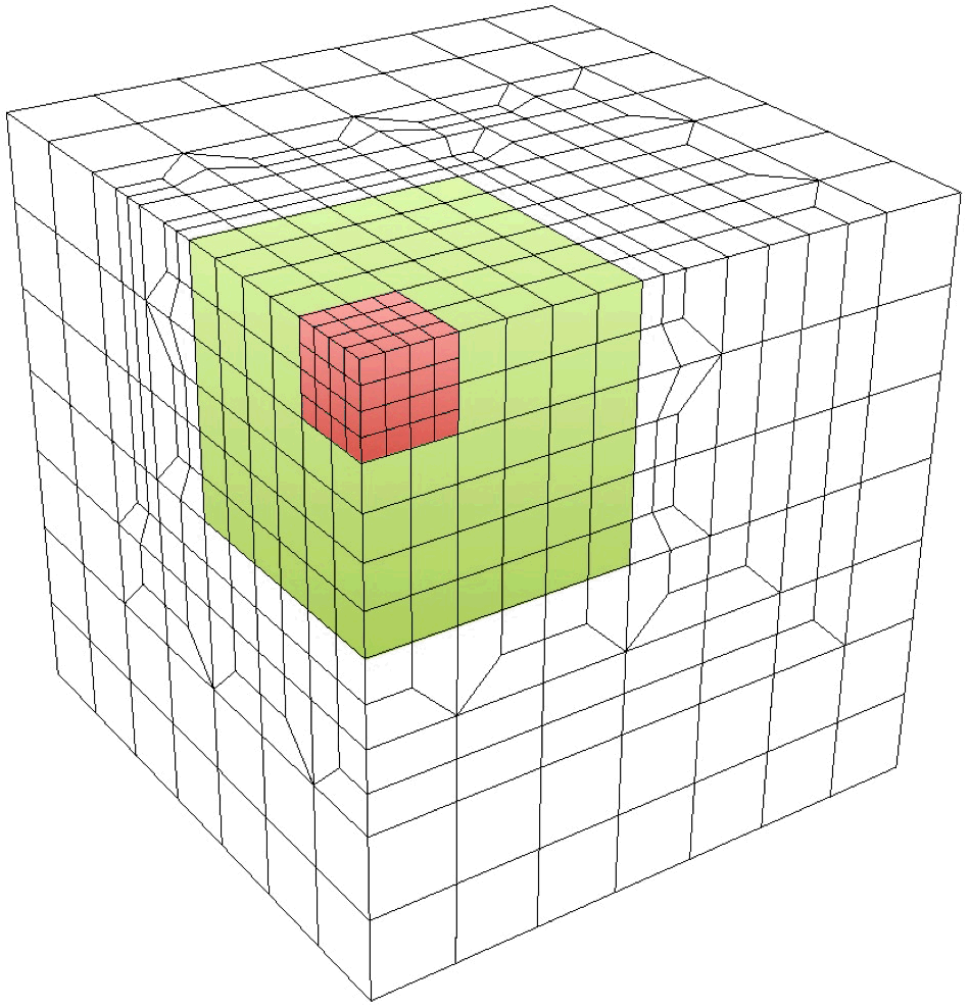

Multi-level Refinement

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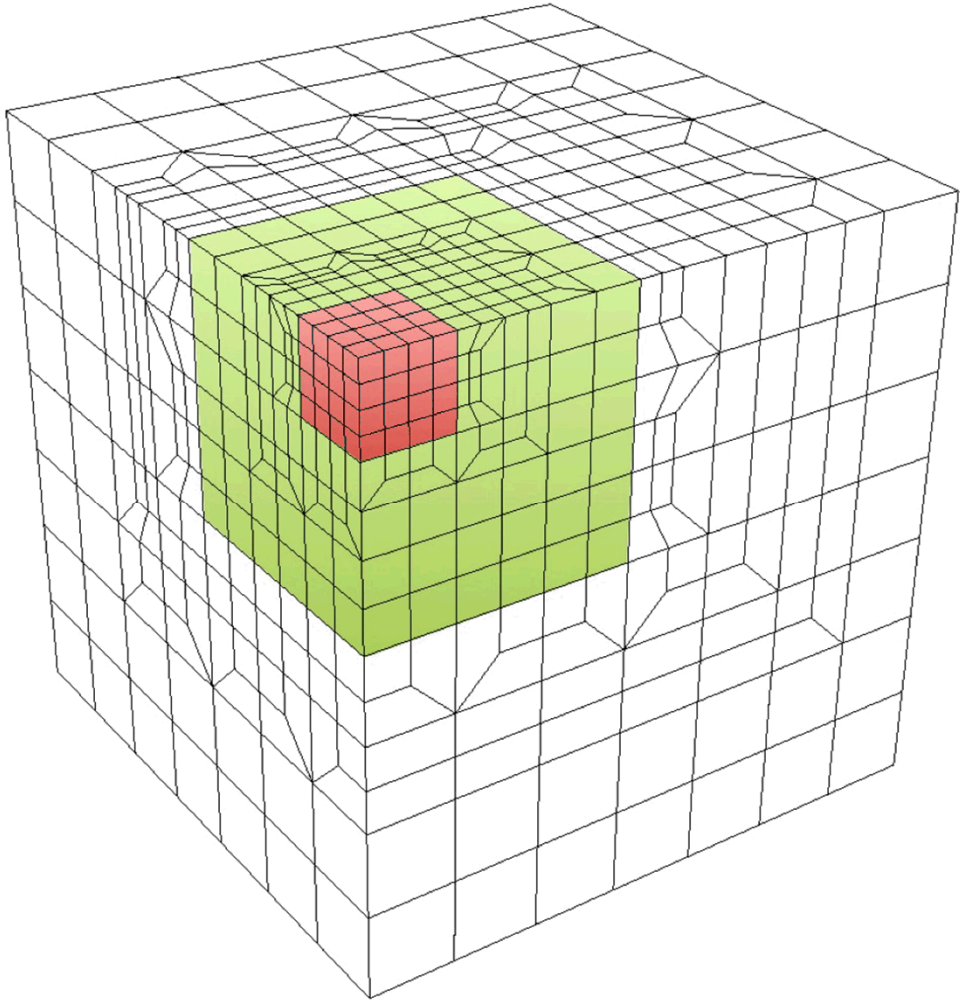

Multi-level Refinement

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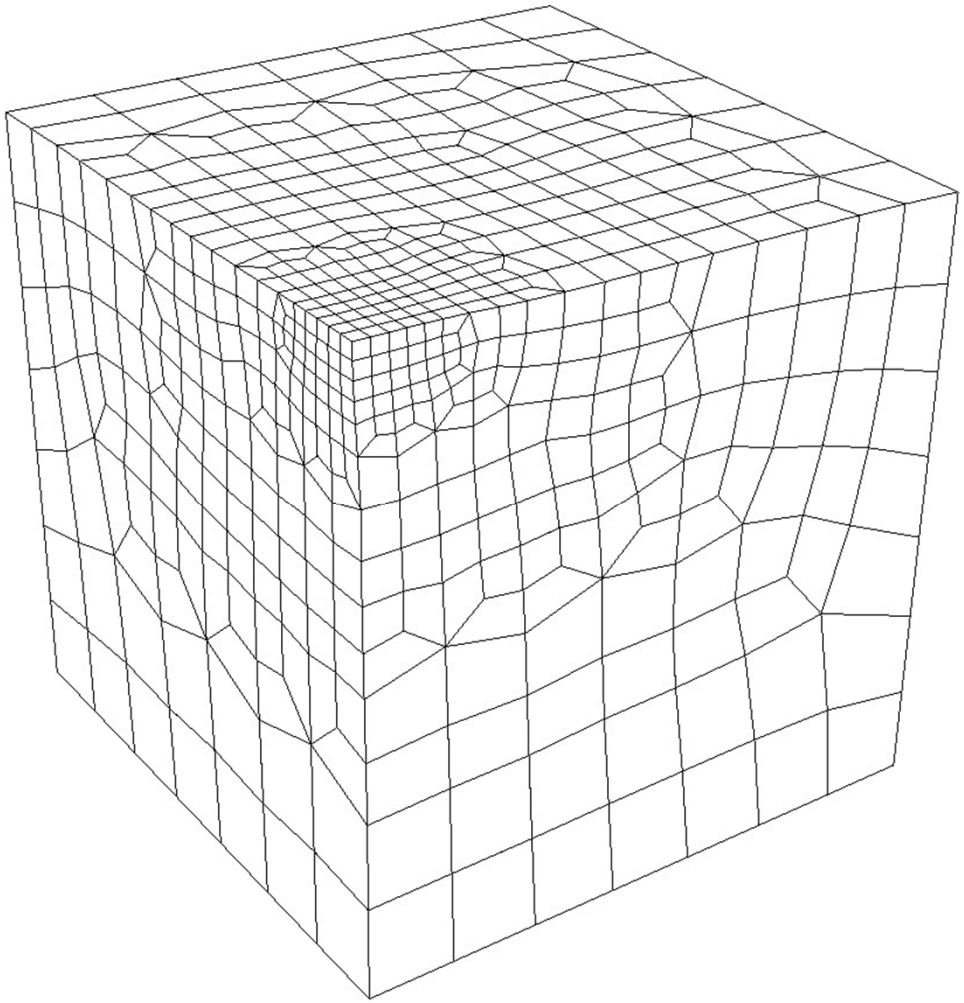
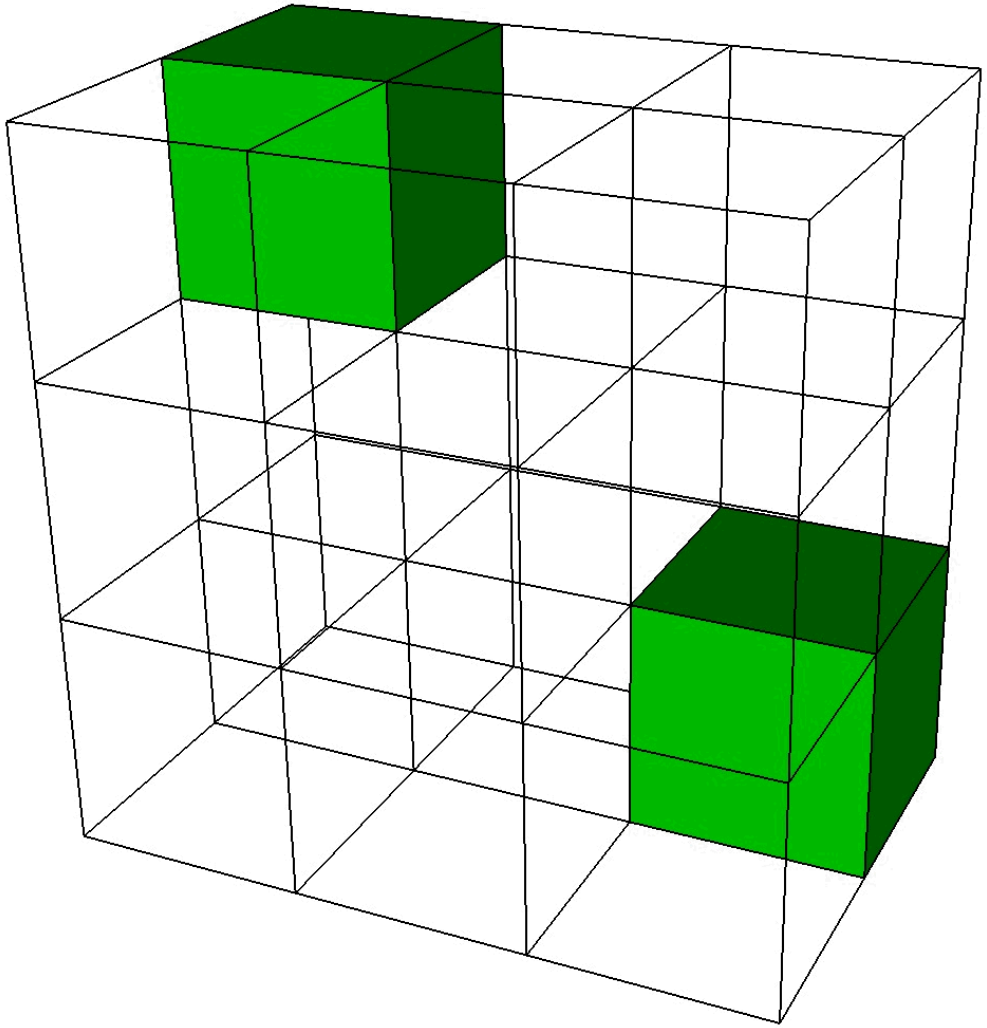


Additional 3D Node Marking



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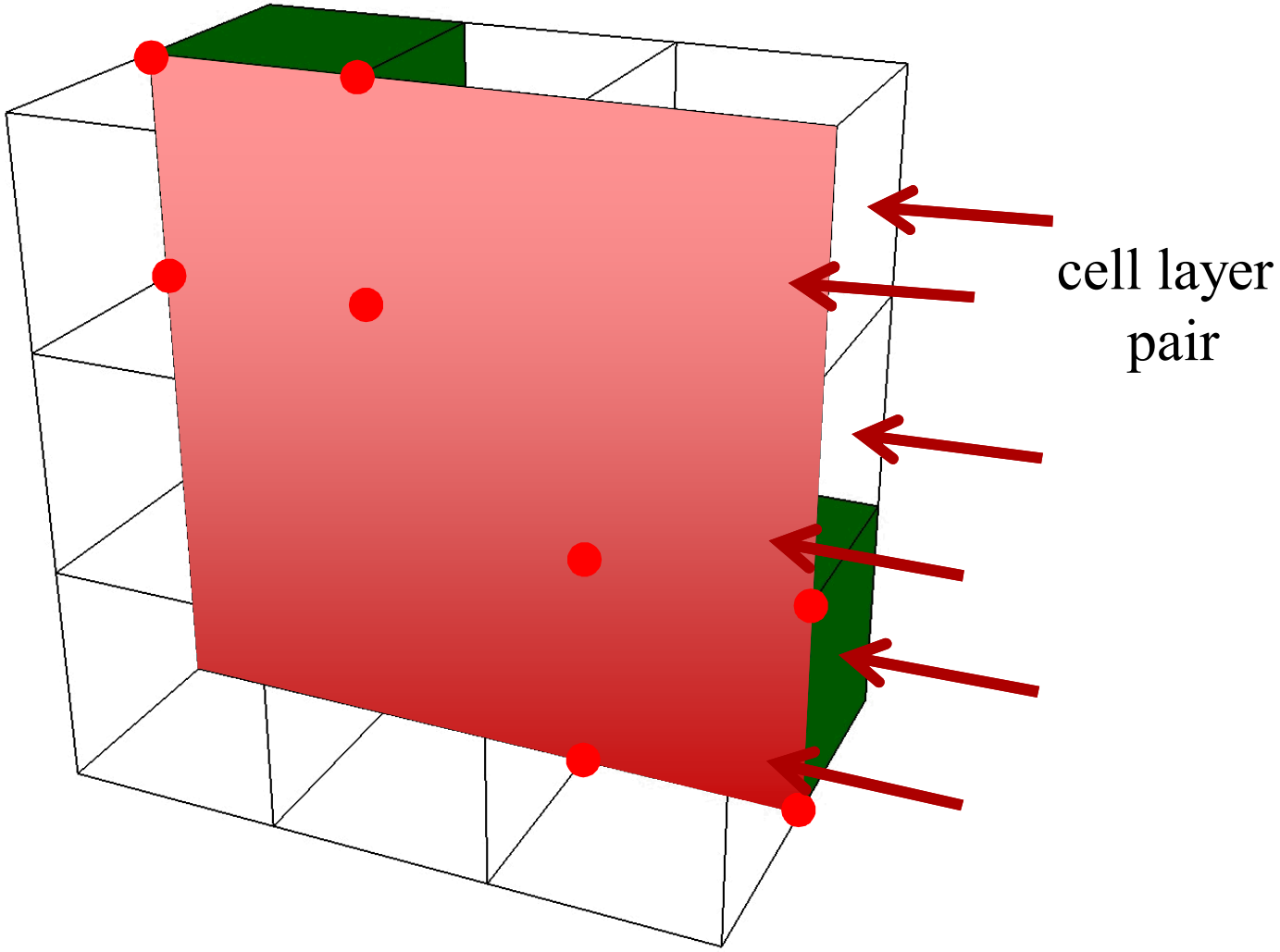

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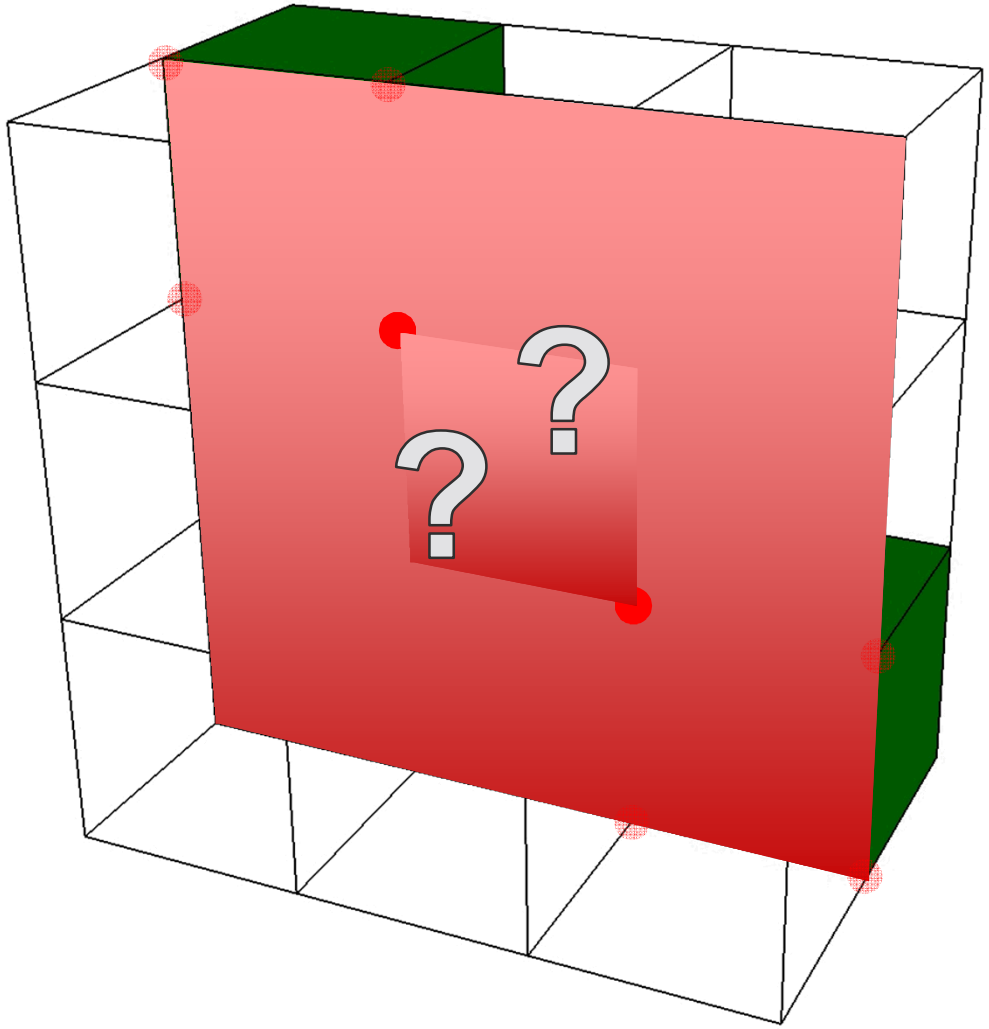

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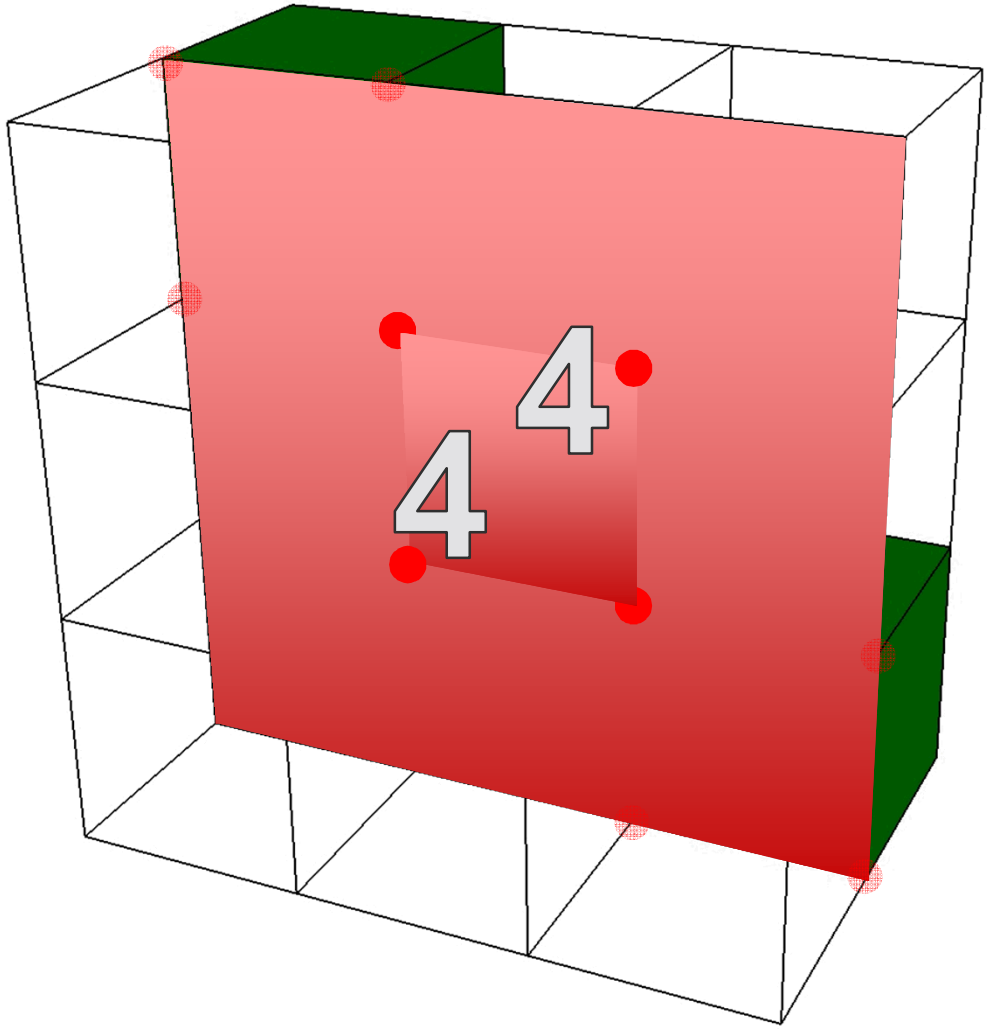

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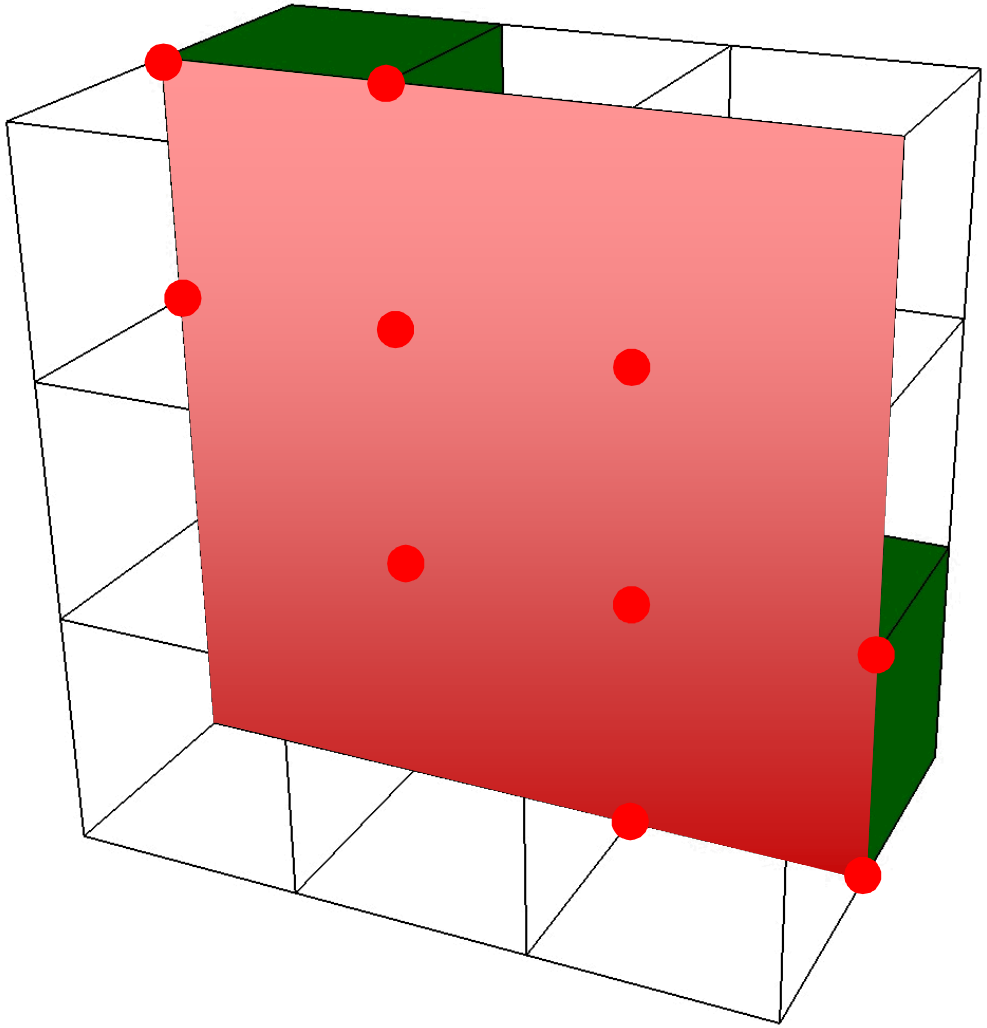

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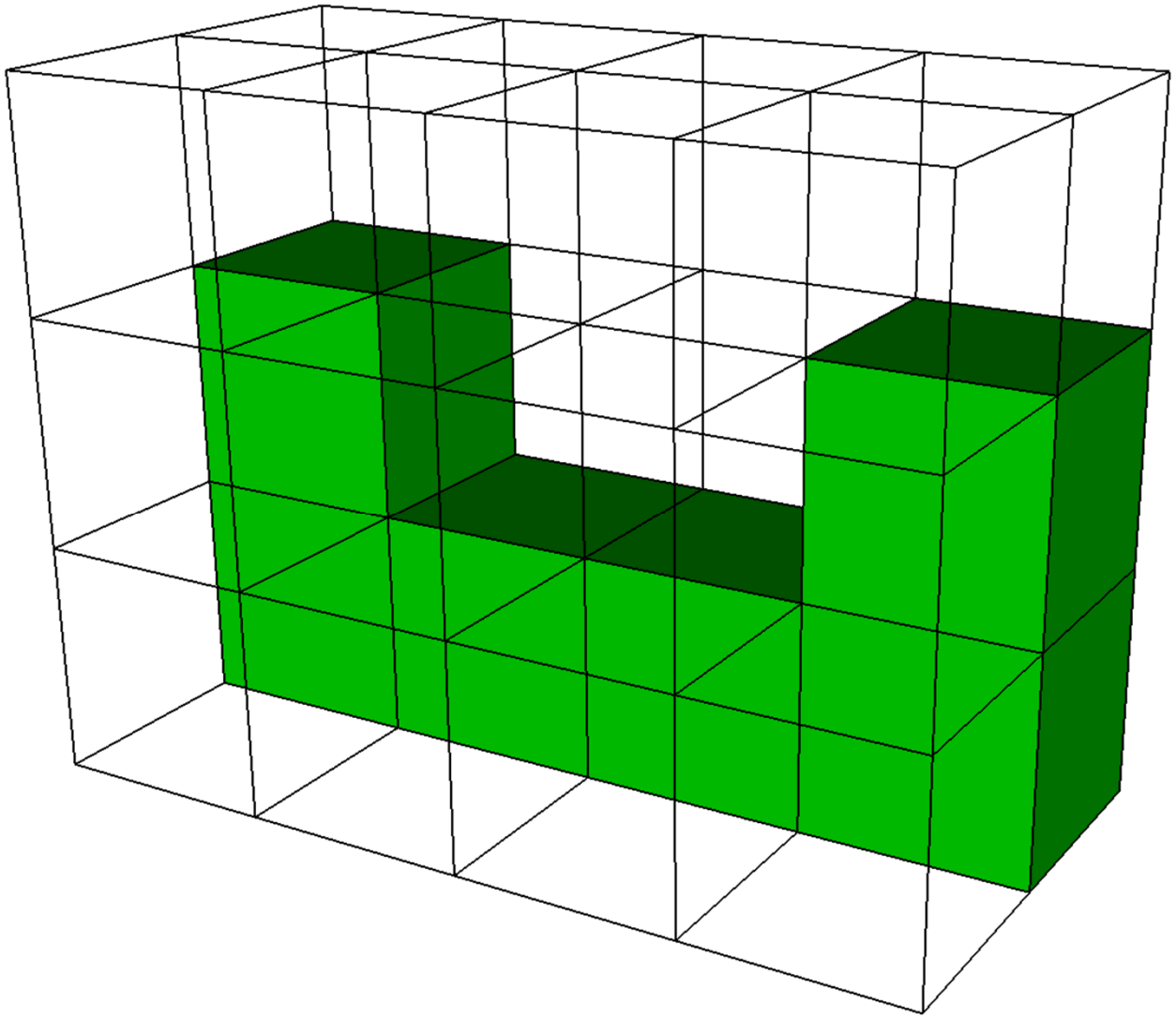

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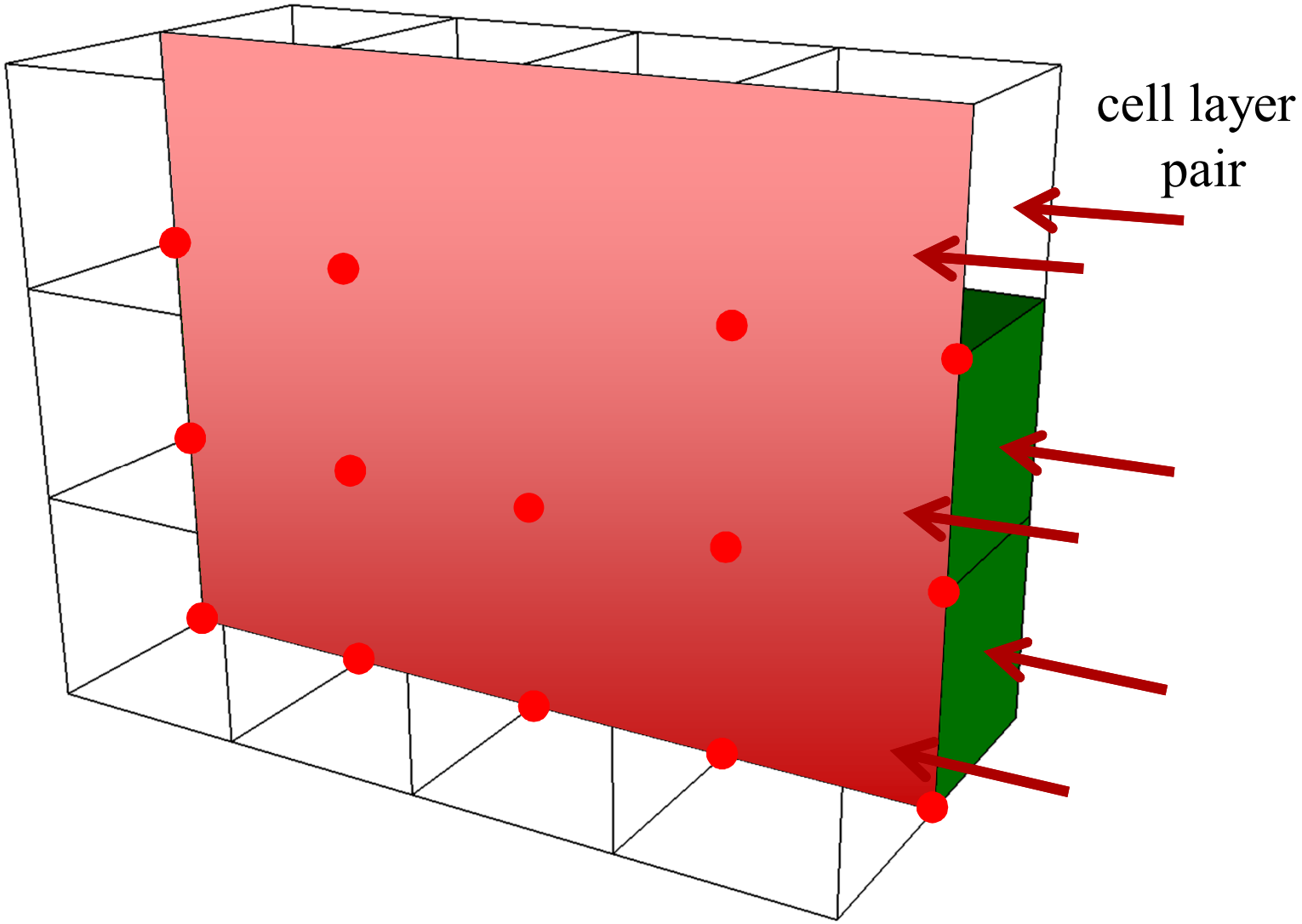

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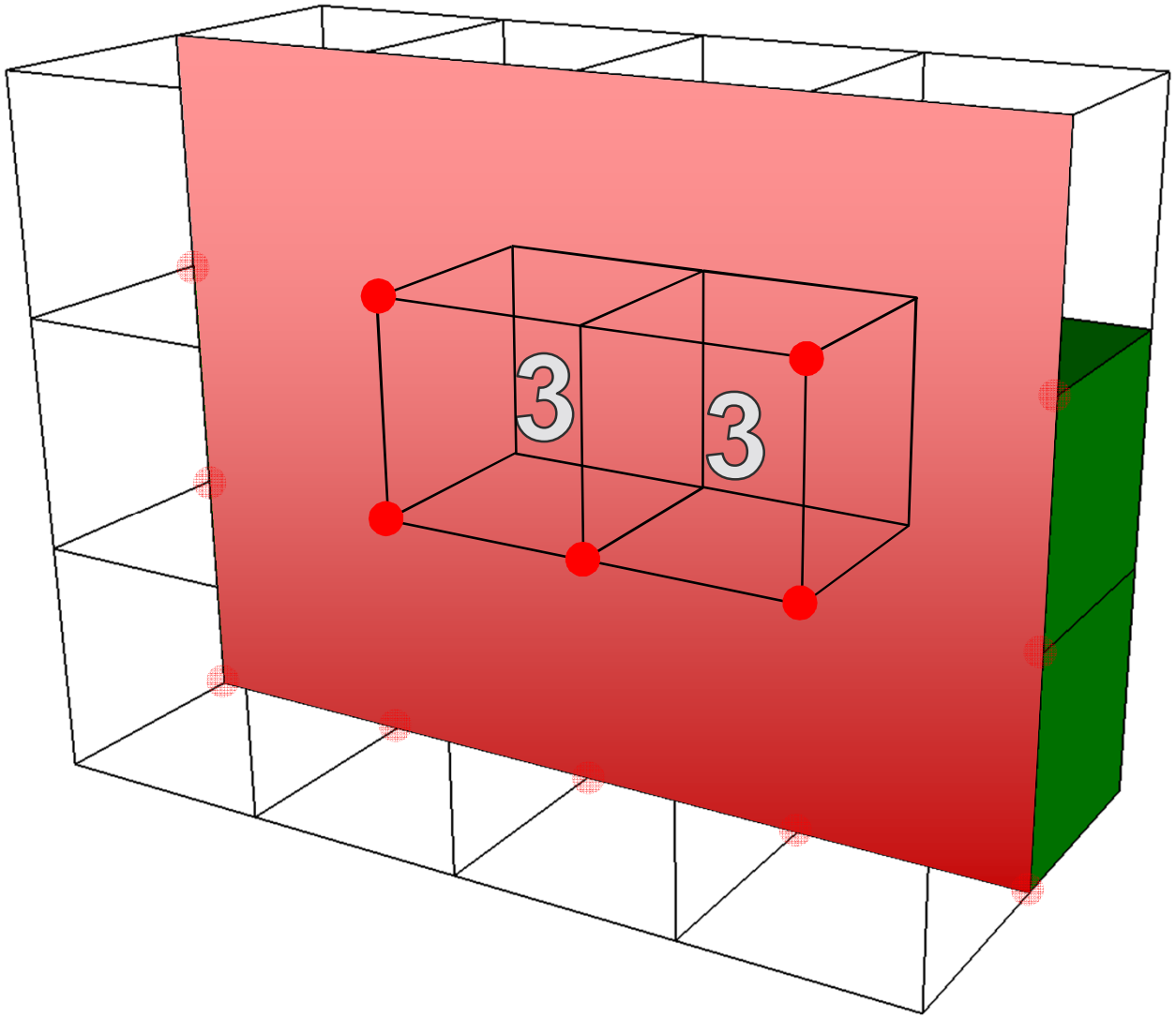

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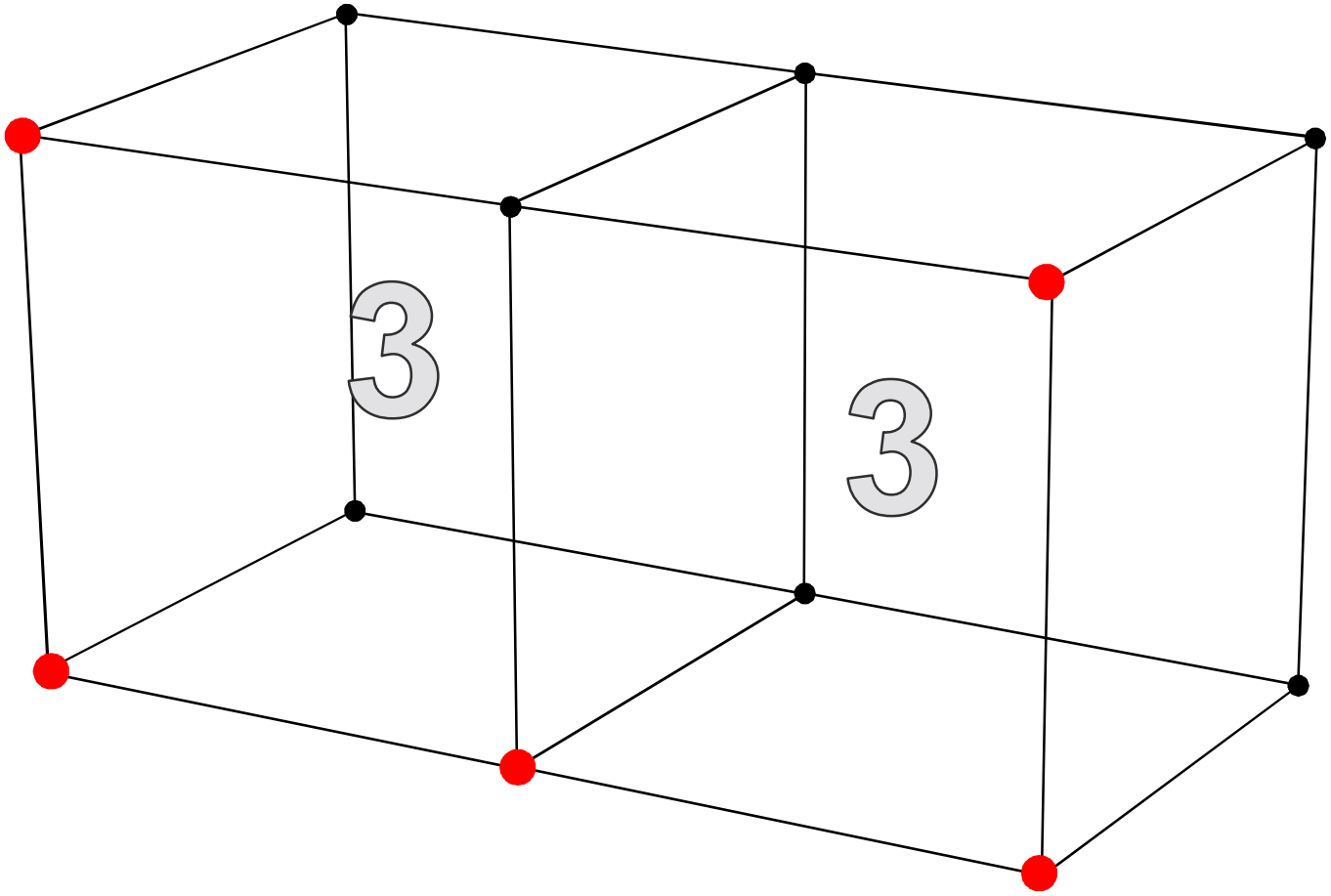

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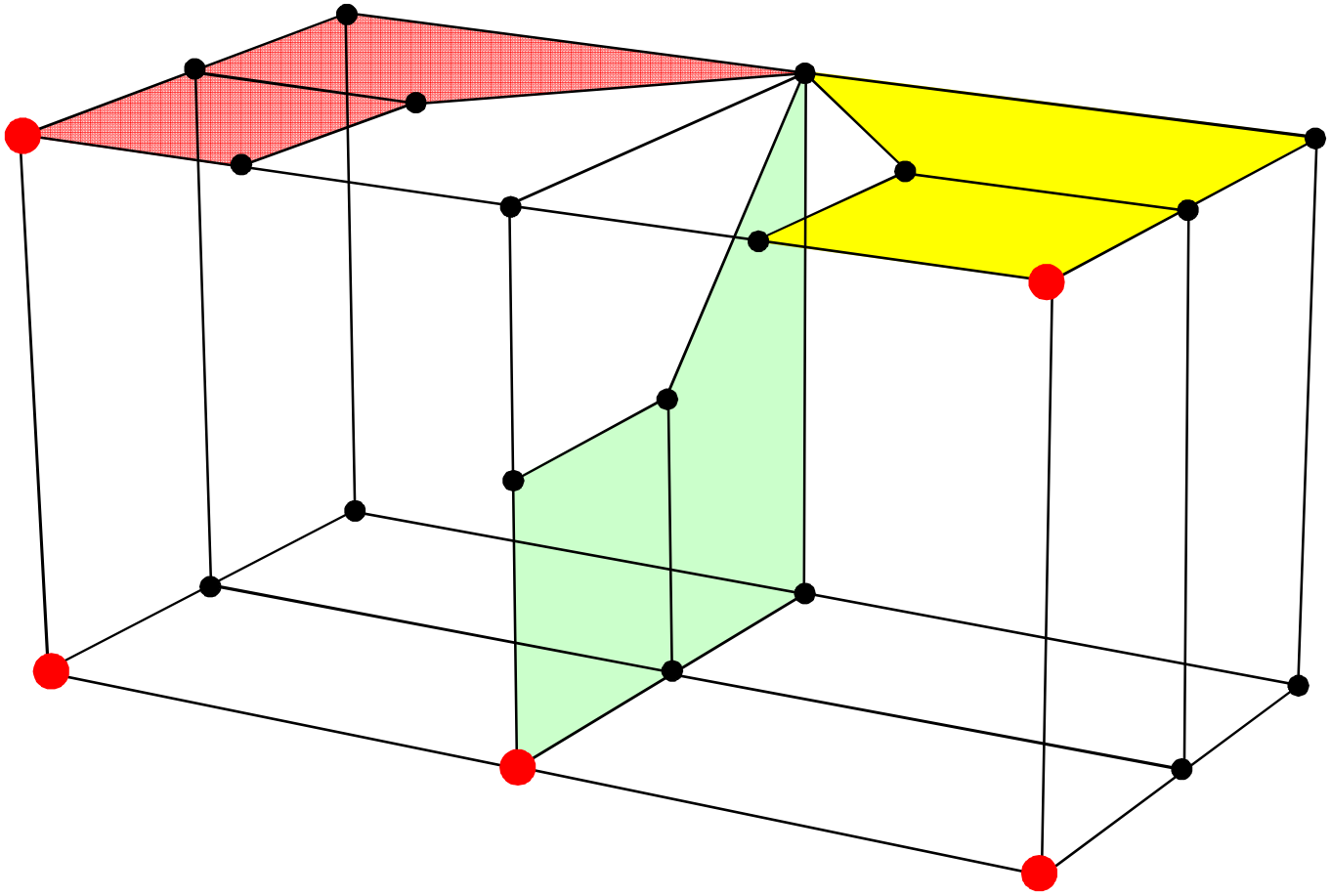

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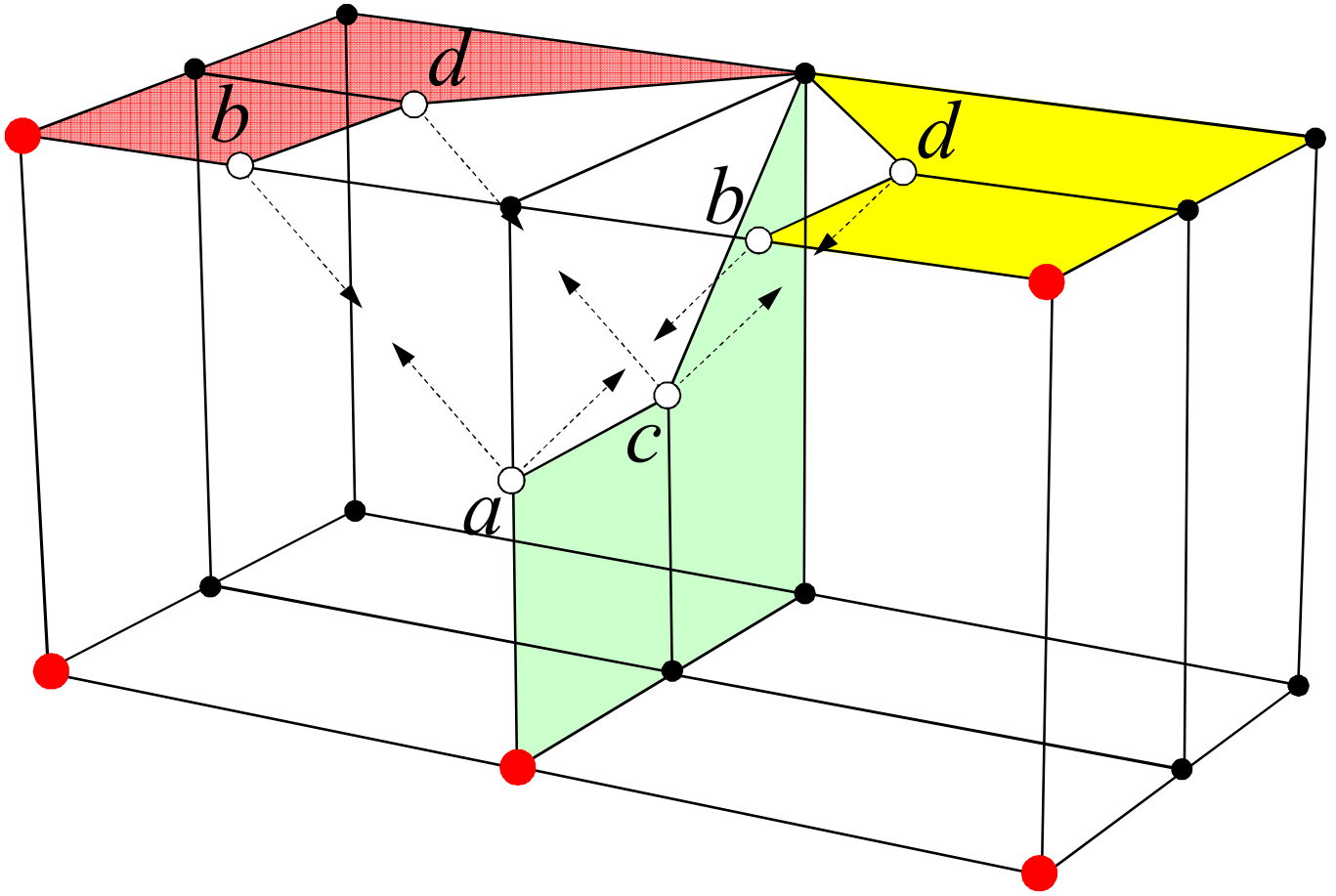

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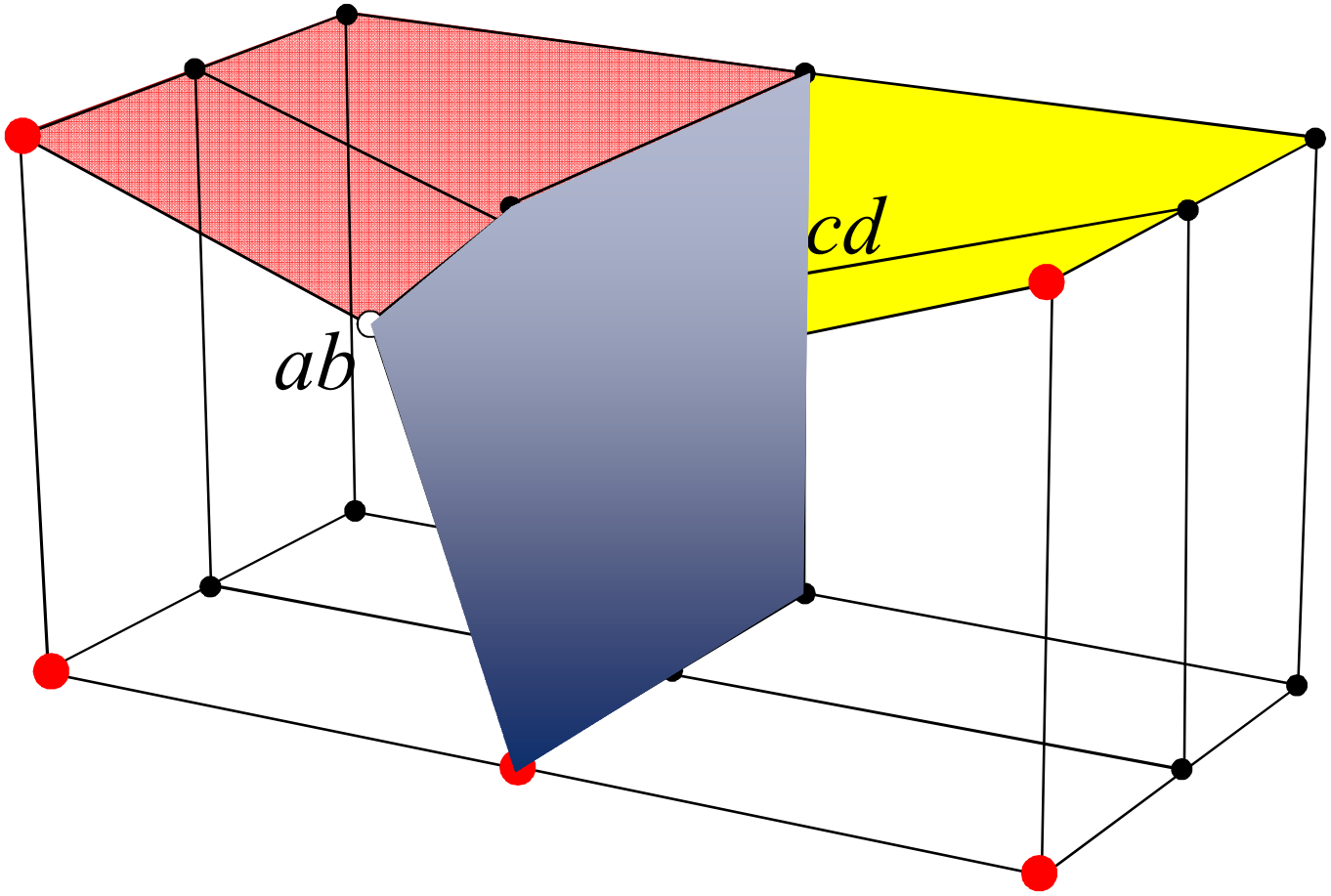

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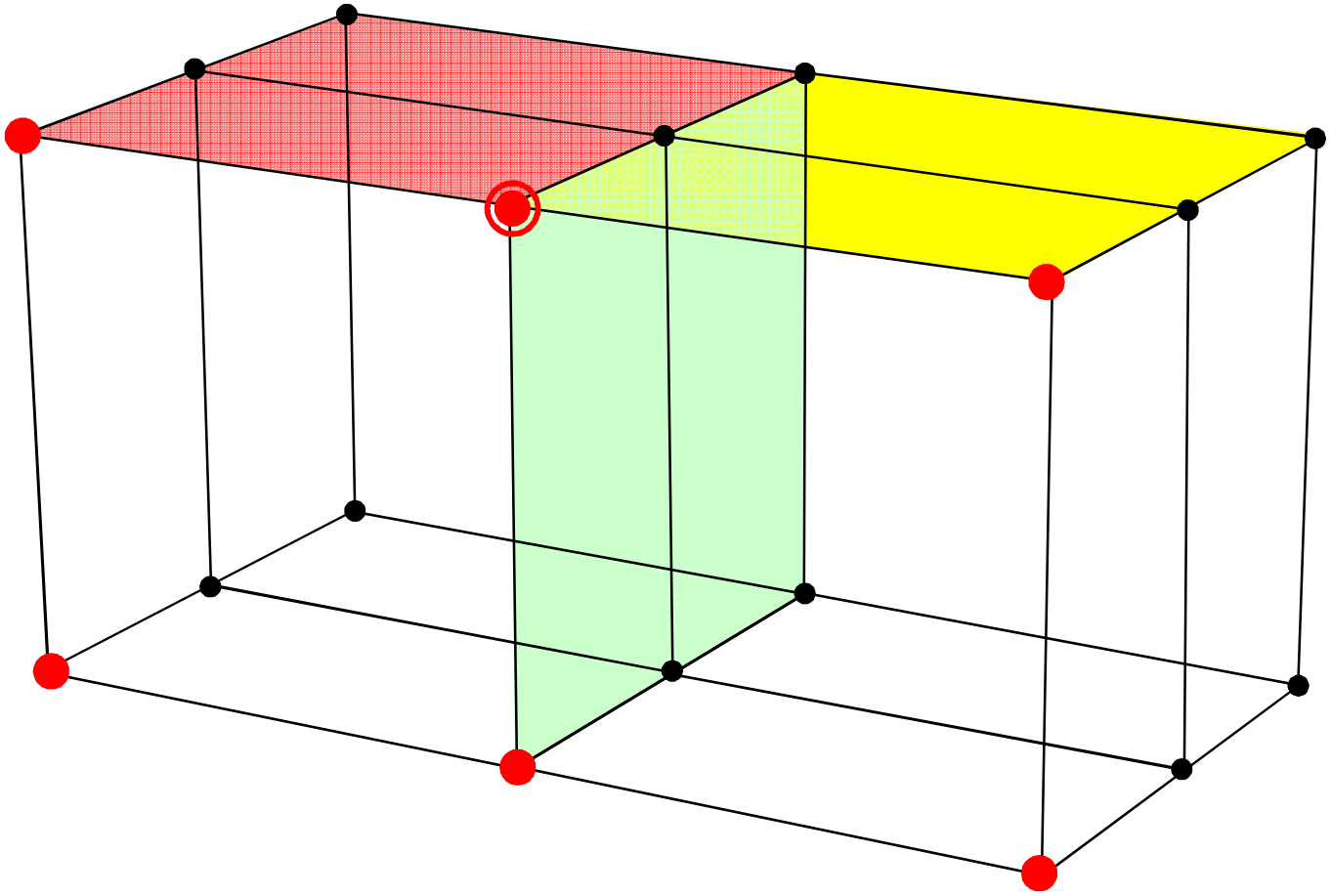

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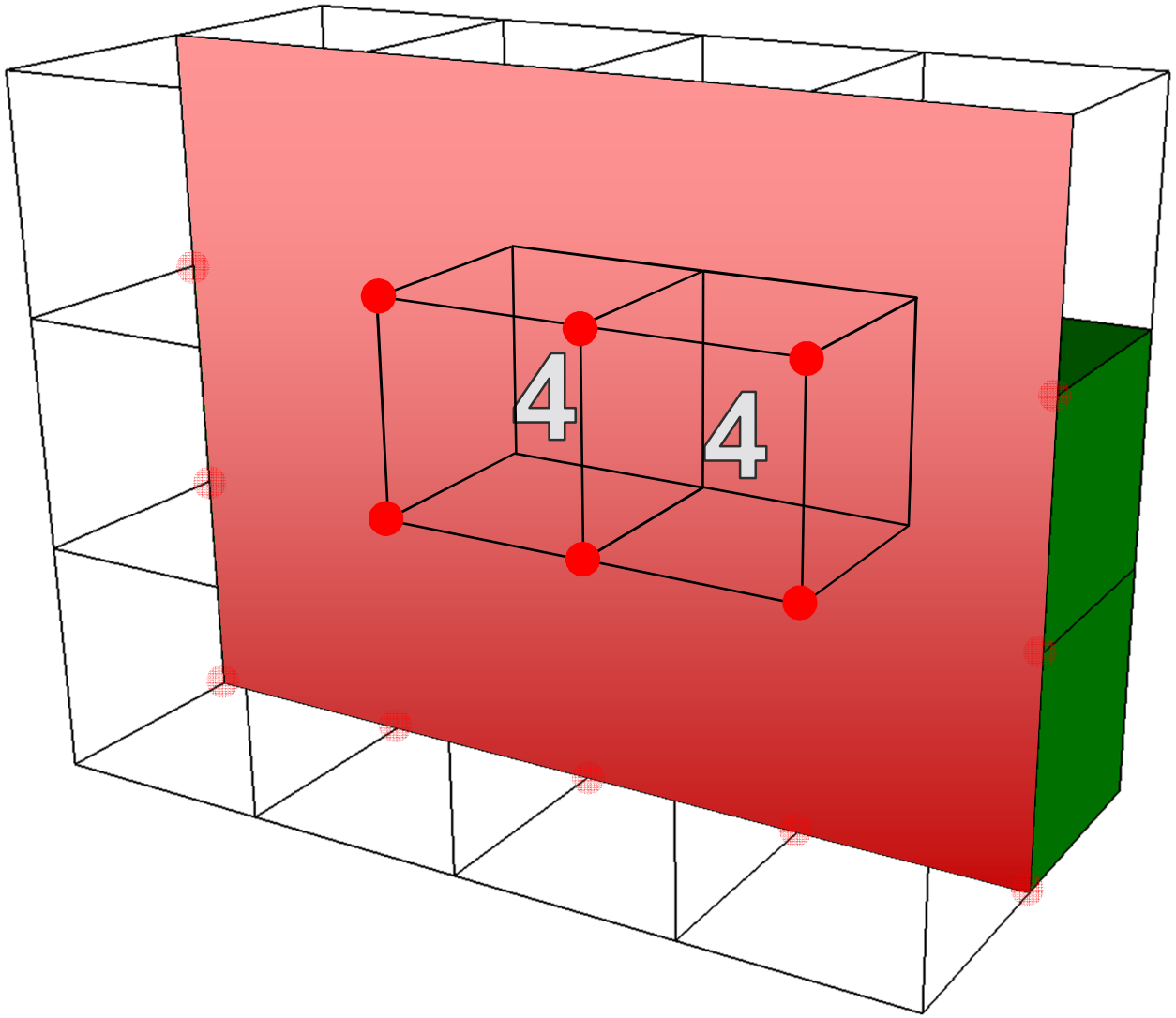

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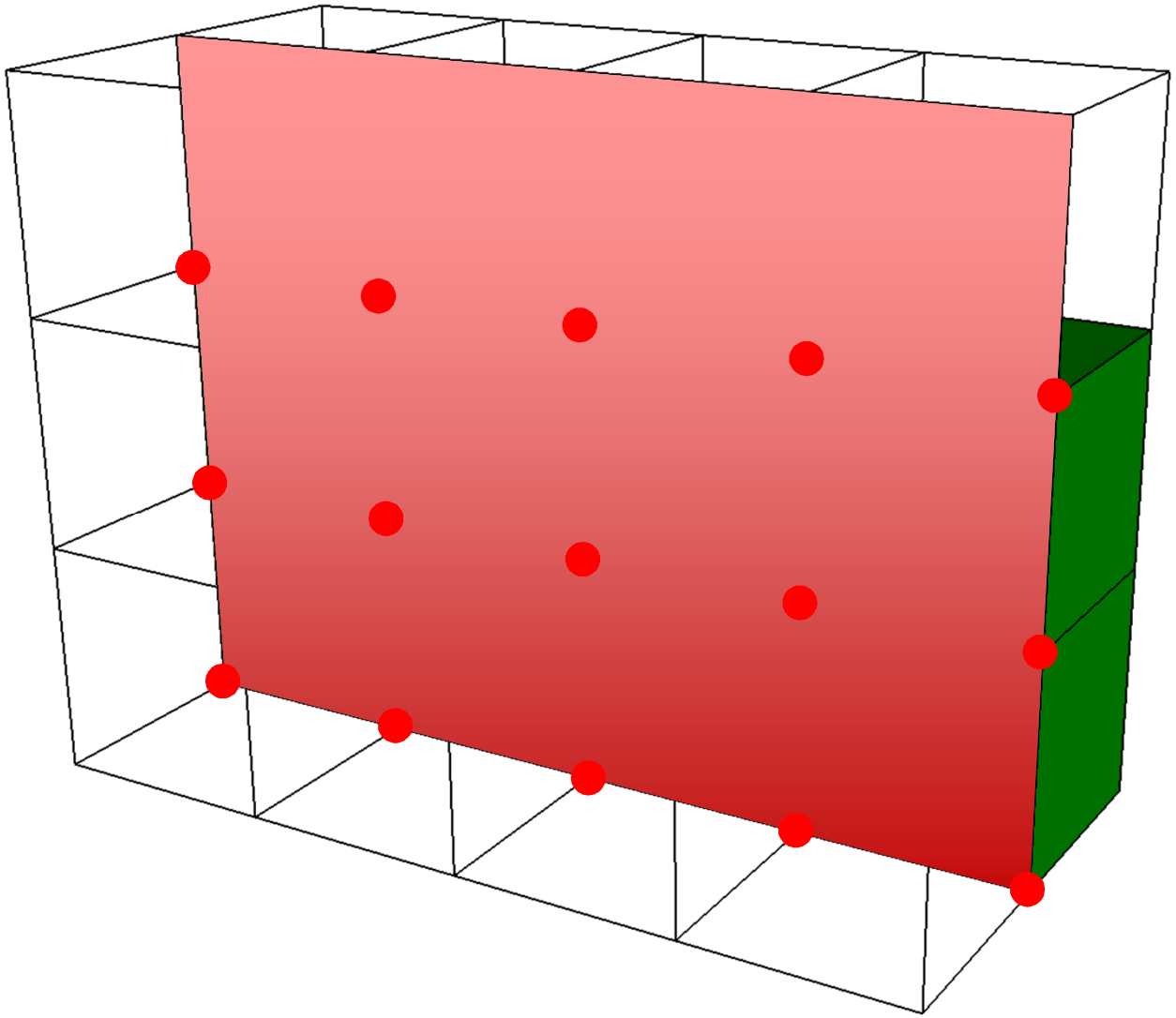

Example Refinement

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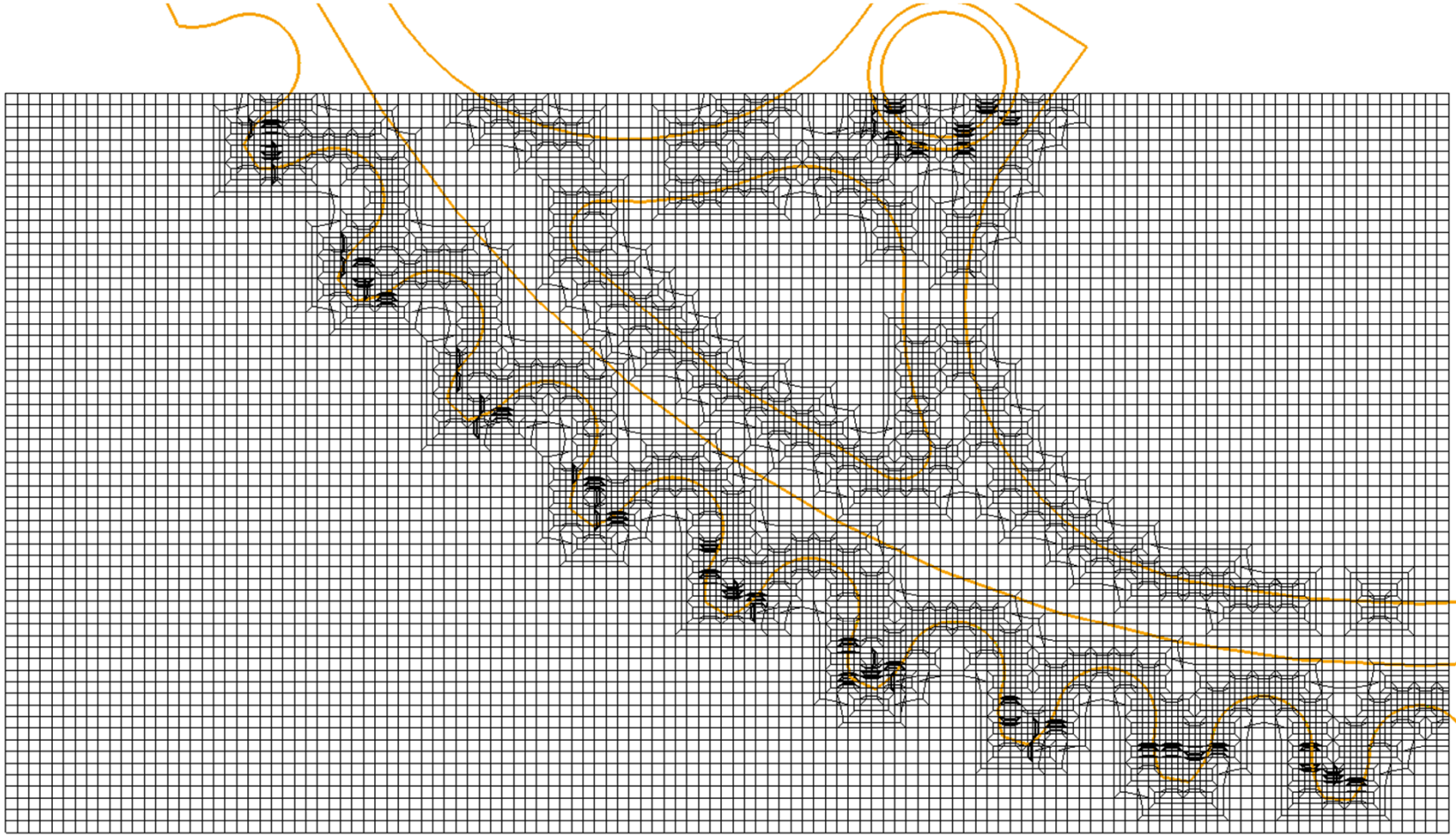
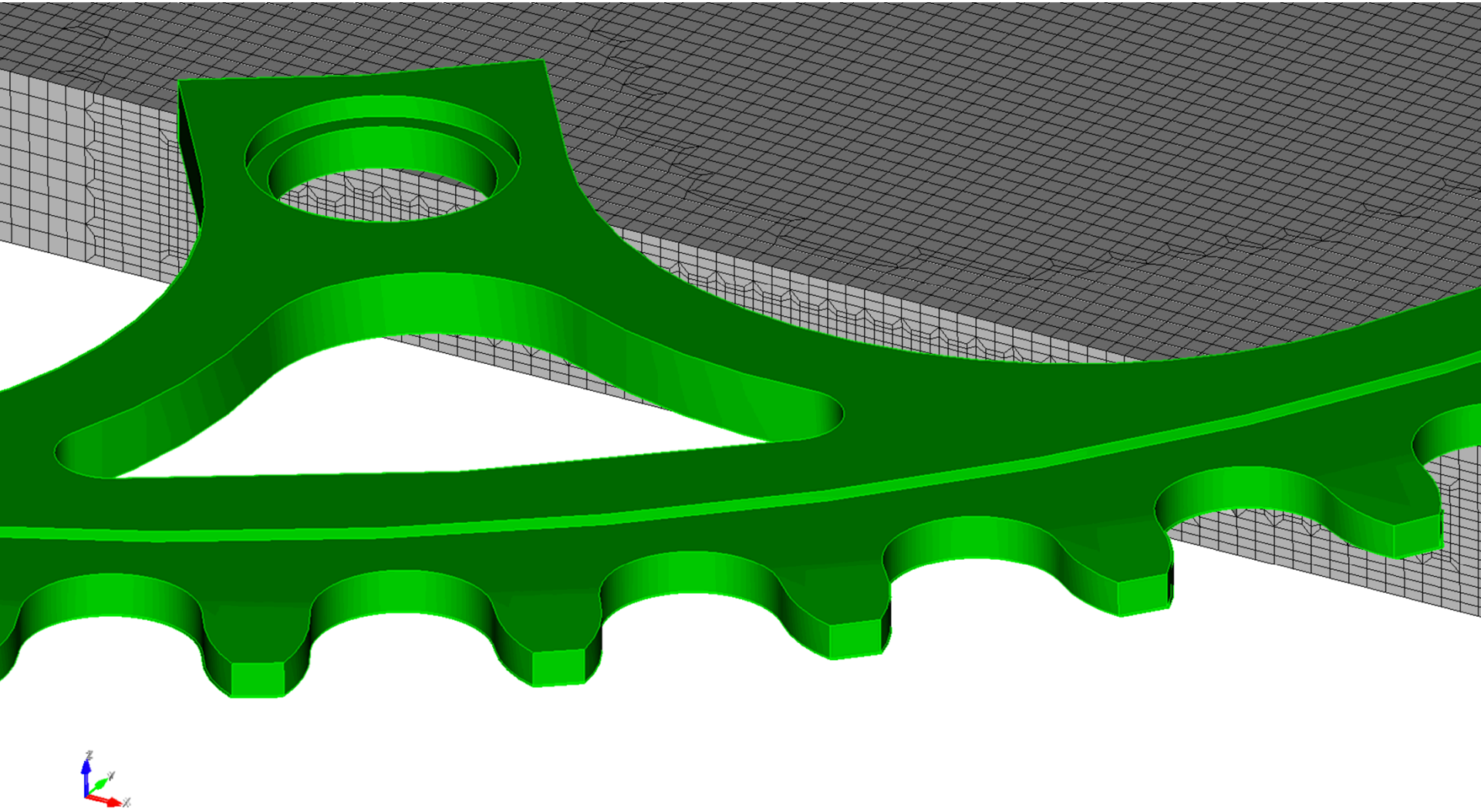
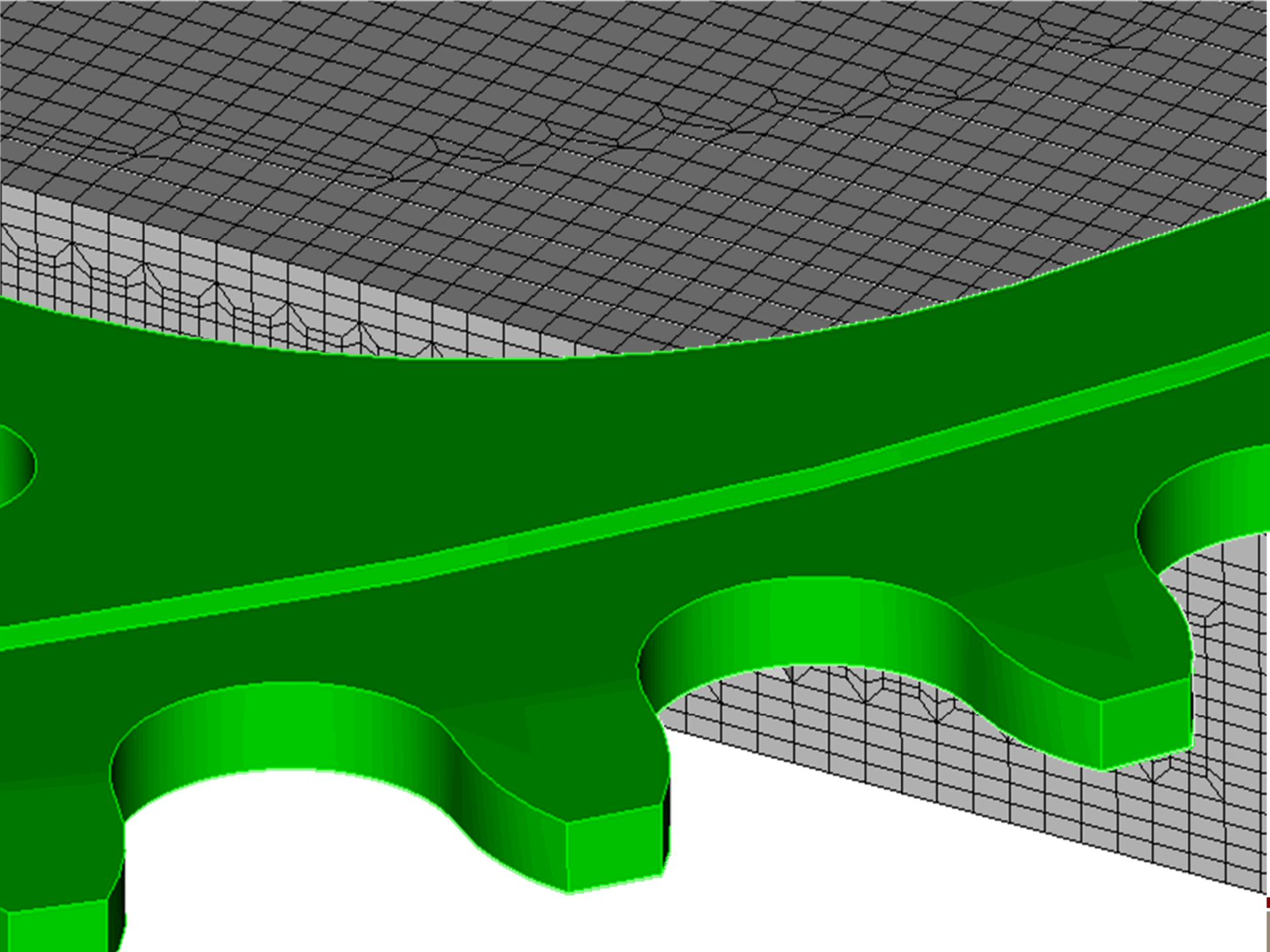


Example Refinement

Sandia National Laboratories





Example Refinement

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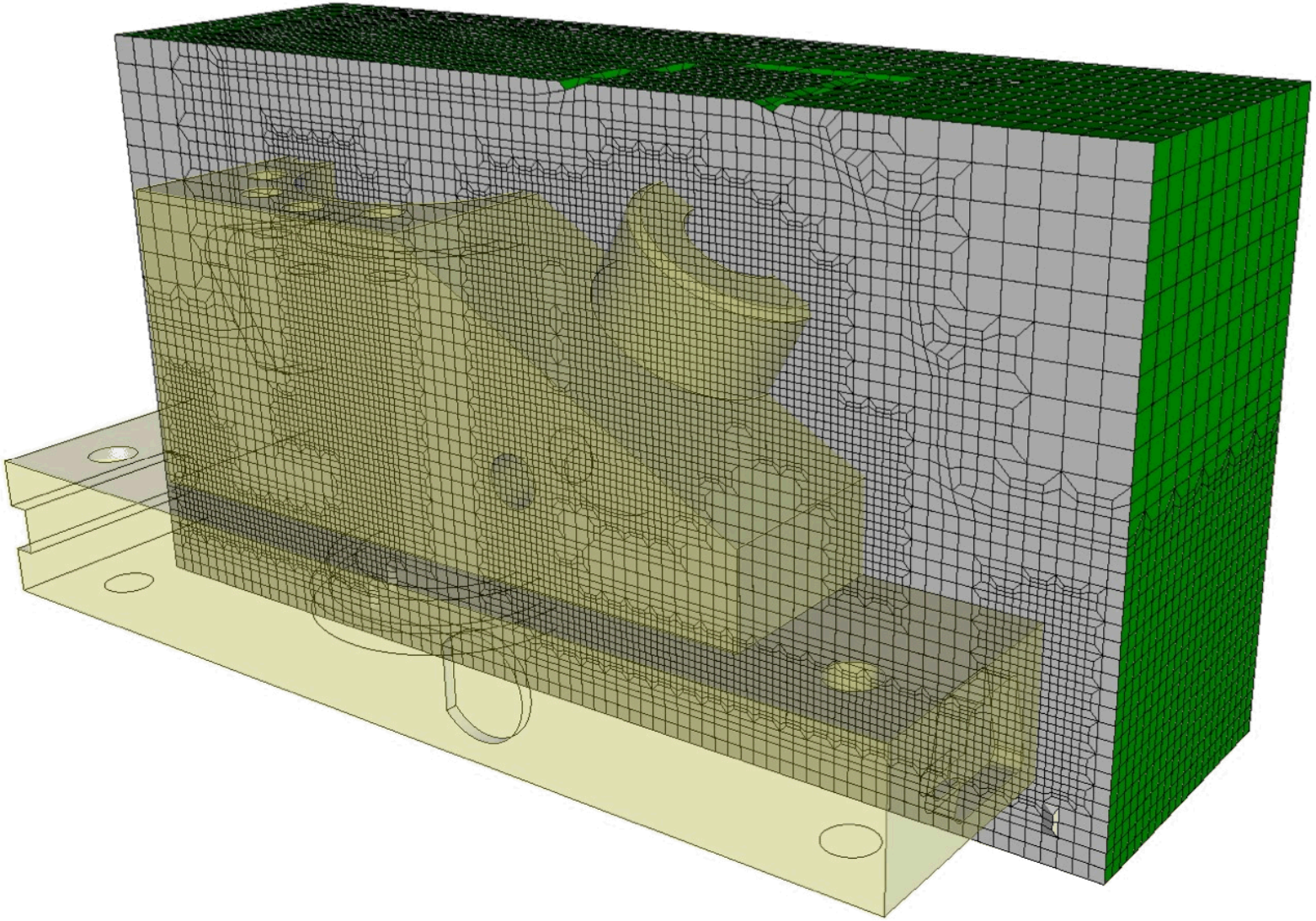

Example Refinement

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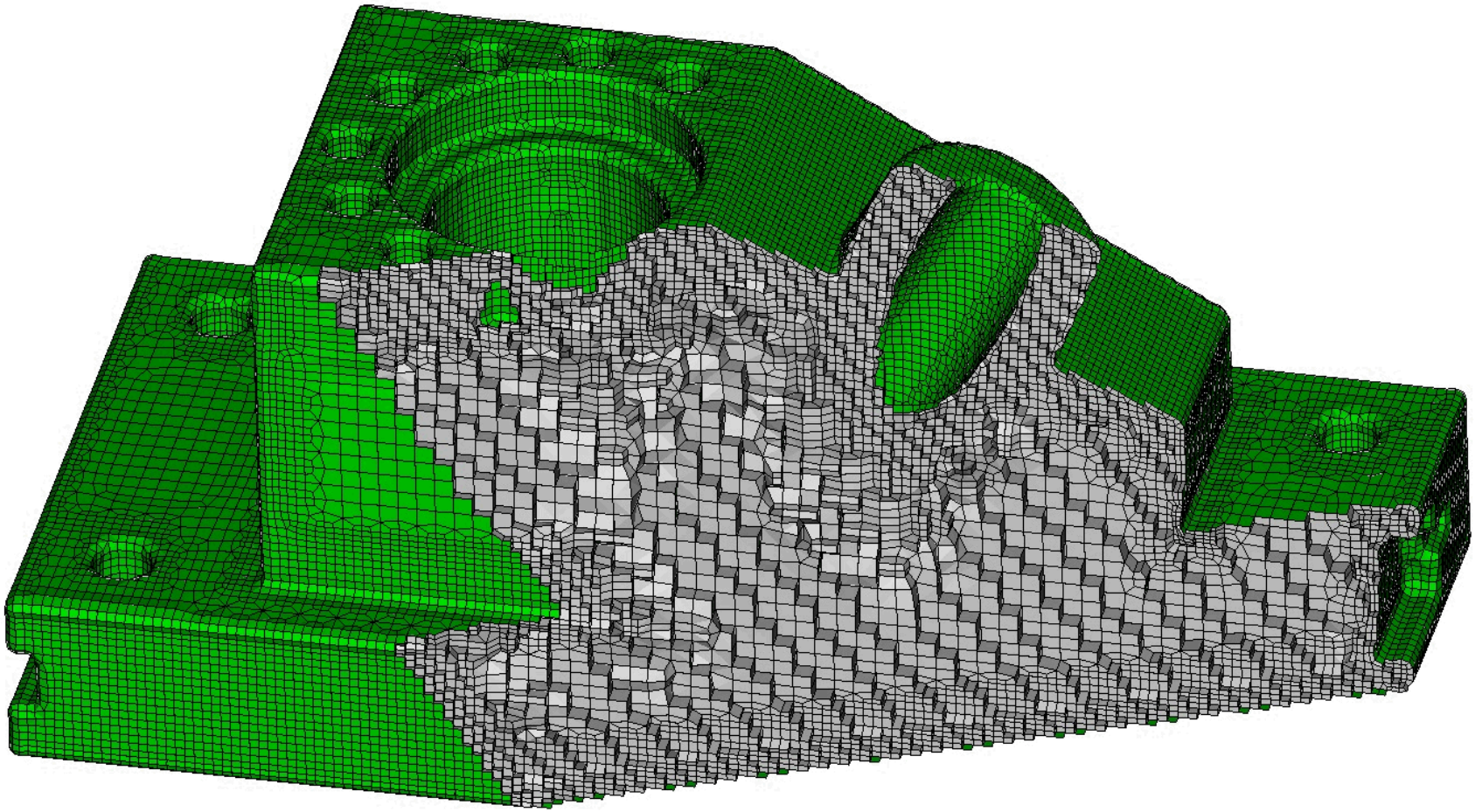

Example Refi

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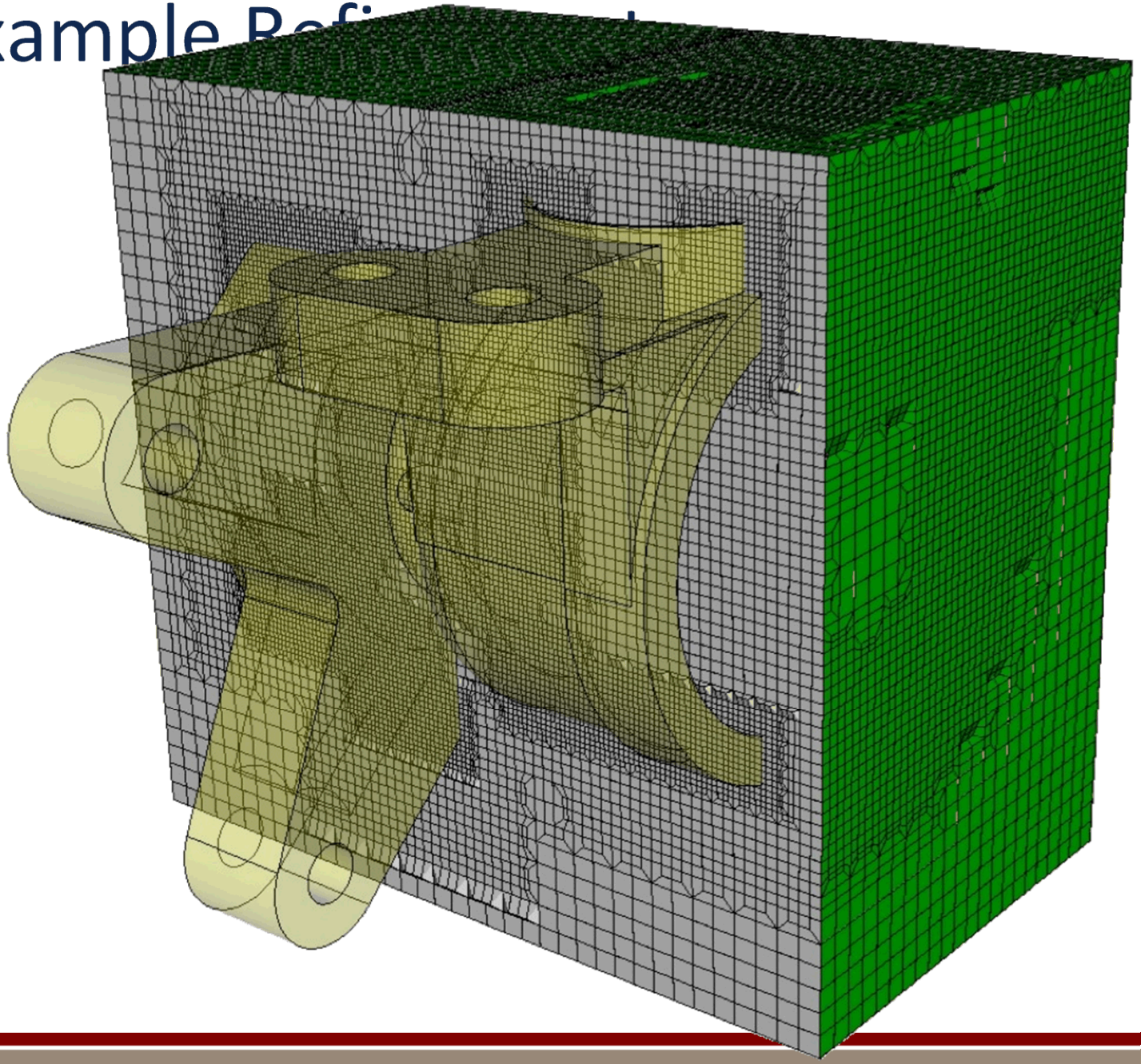
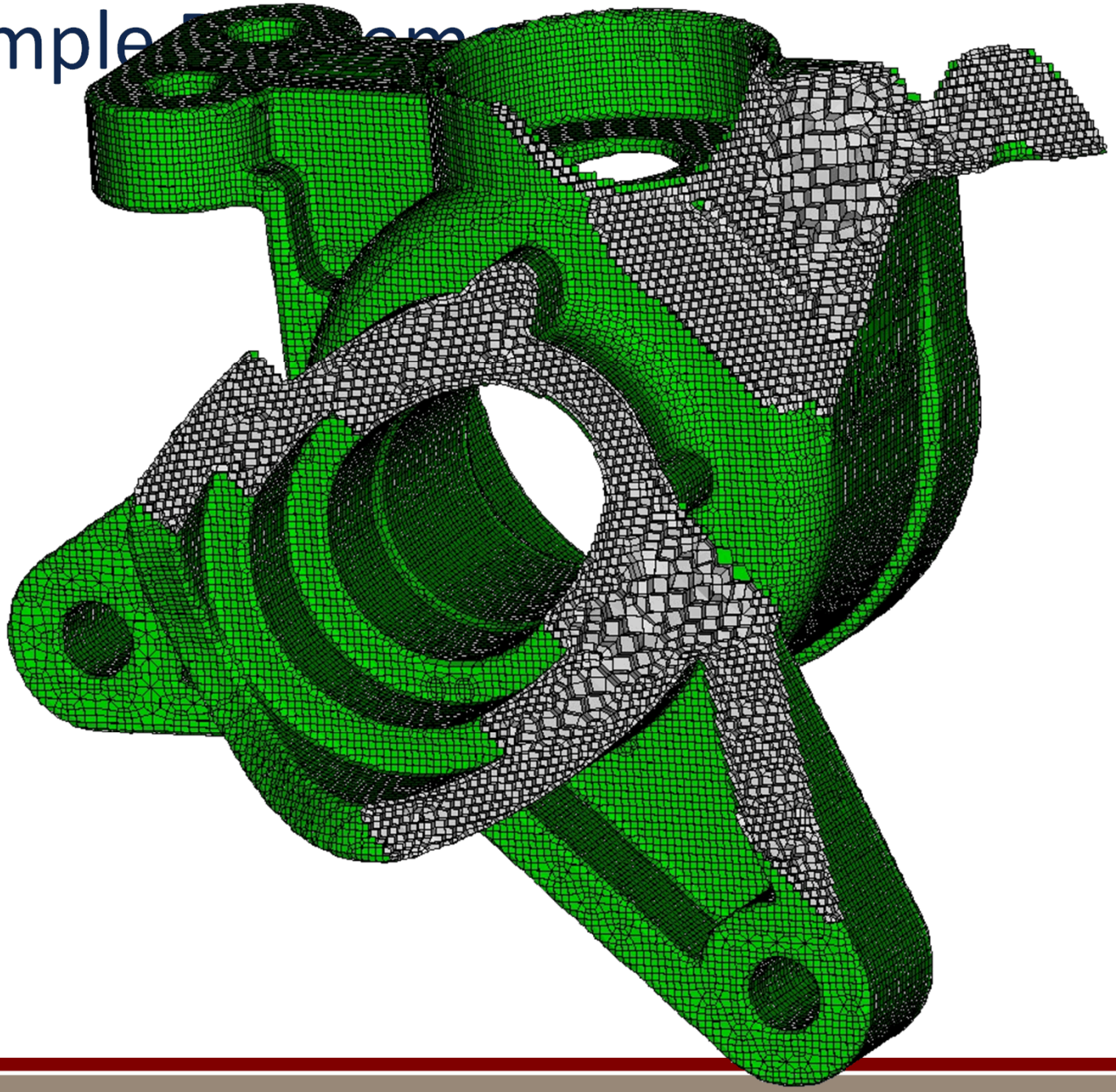


Example



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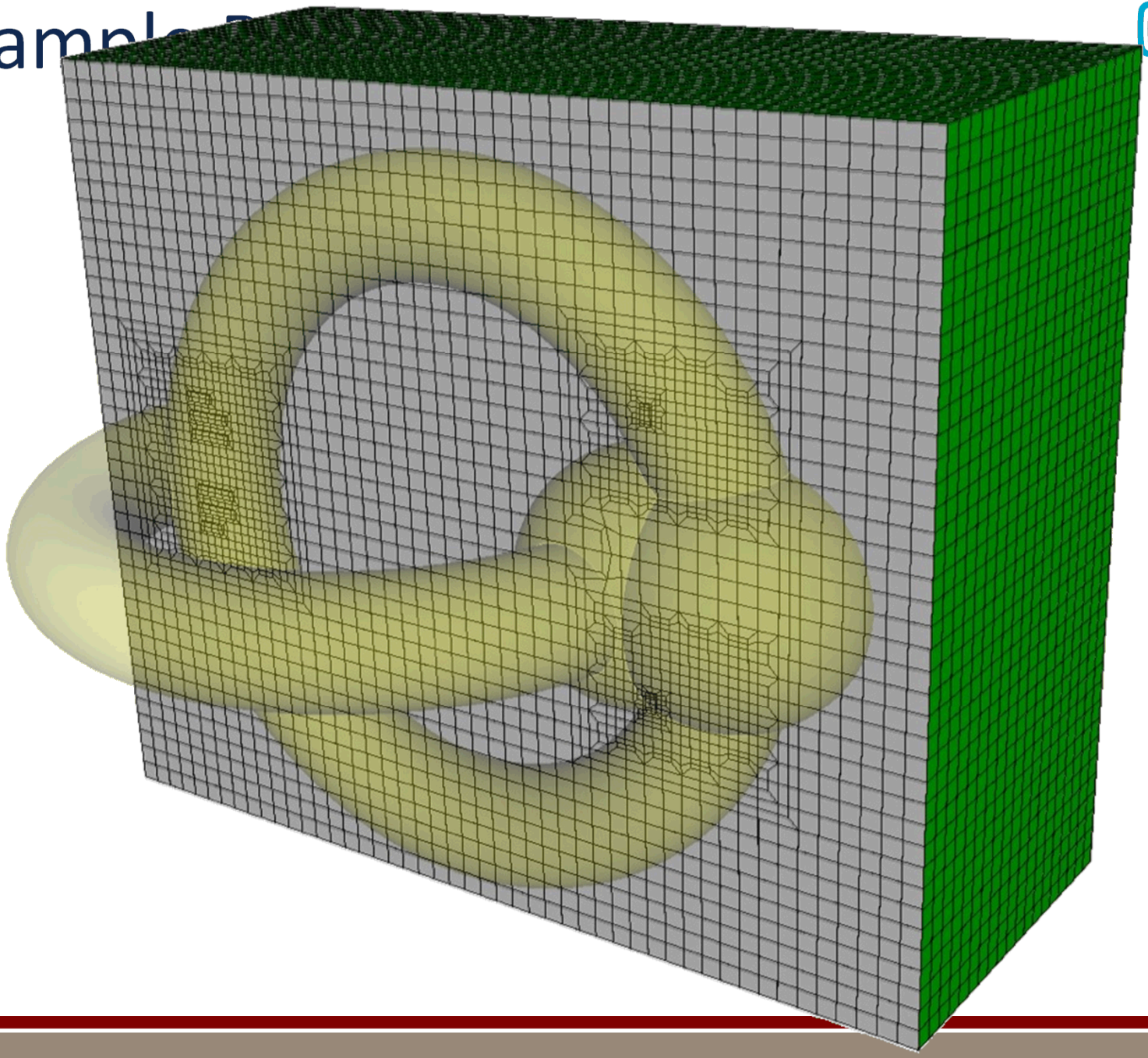
Example



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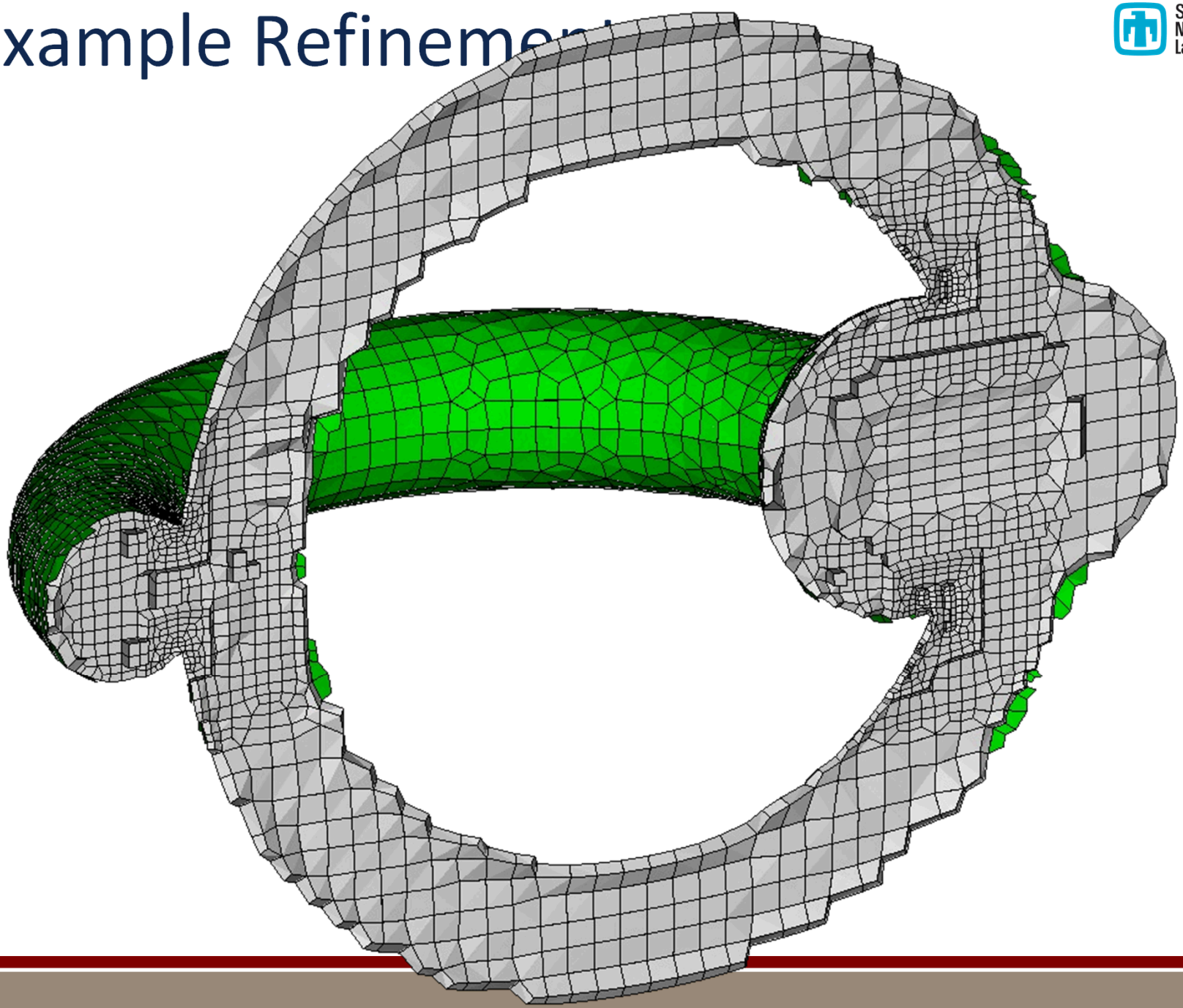
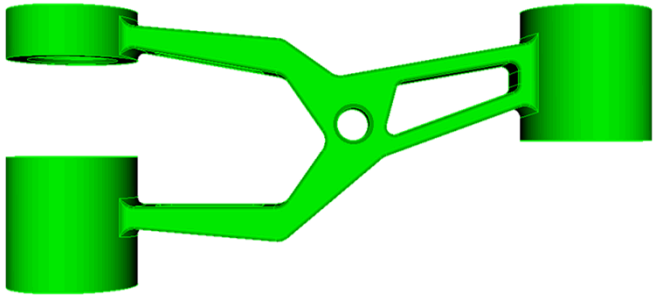
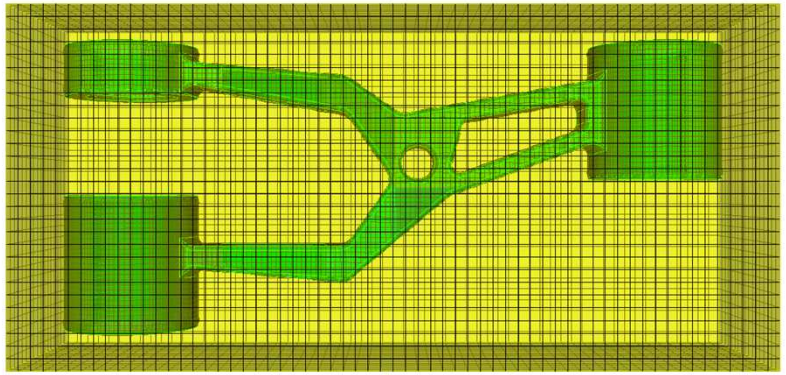
Example Refinement



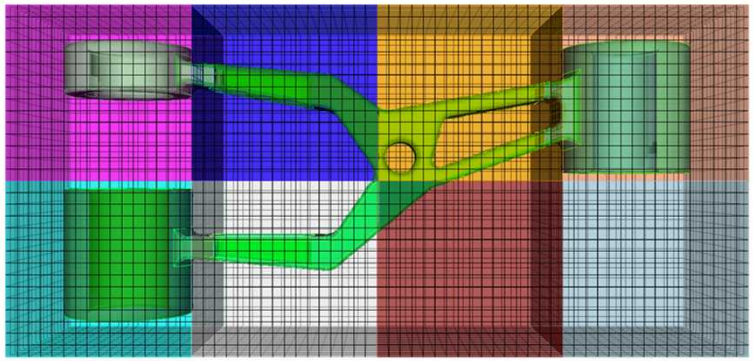
Distributed Parallel



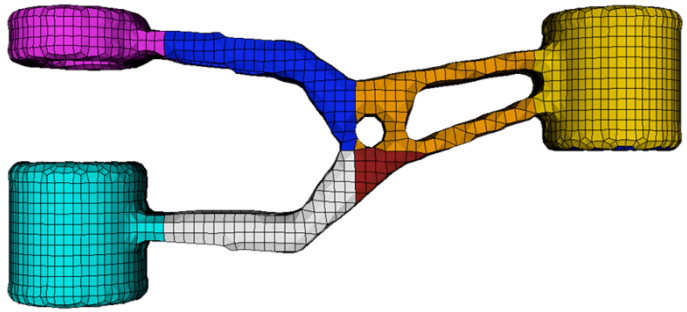
CAD geometry



Global overlay Cartesian grid

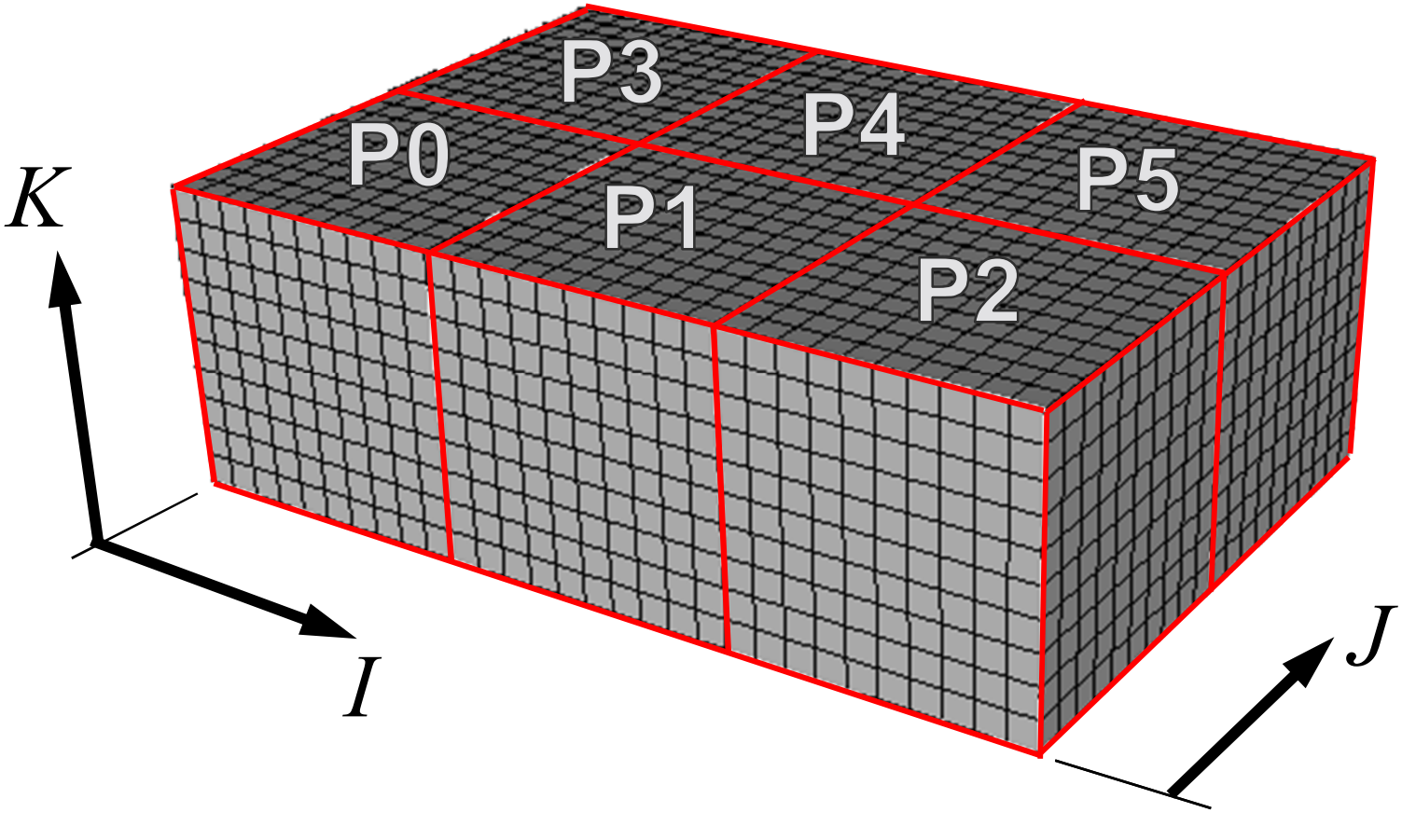


Cartesian grid decomposed and distributed amongst many processors



Each processor independently meshes its portion of Cartesian grid

Distributed Parallel



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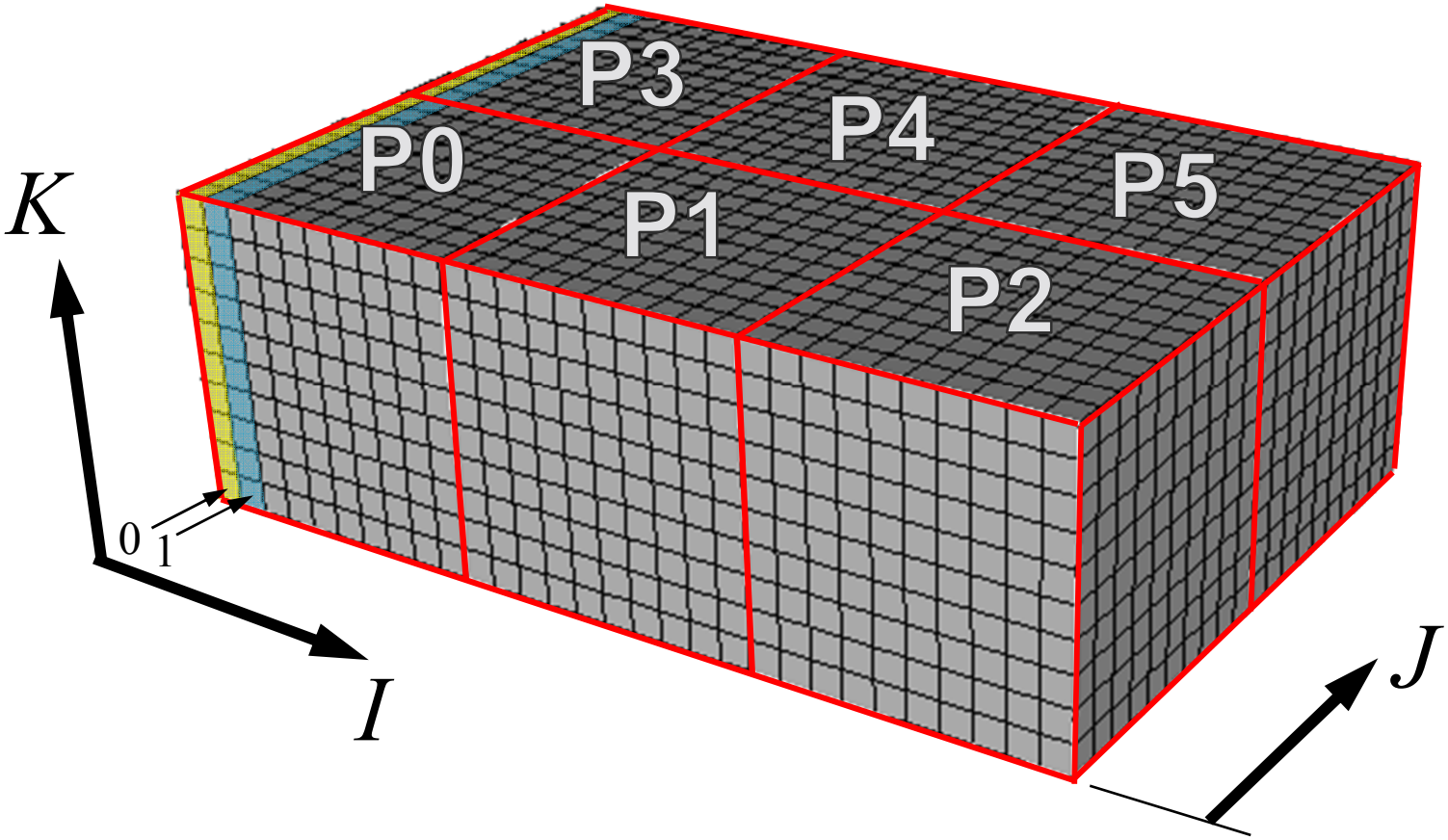

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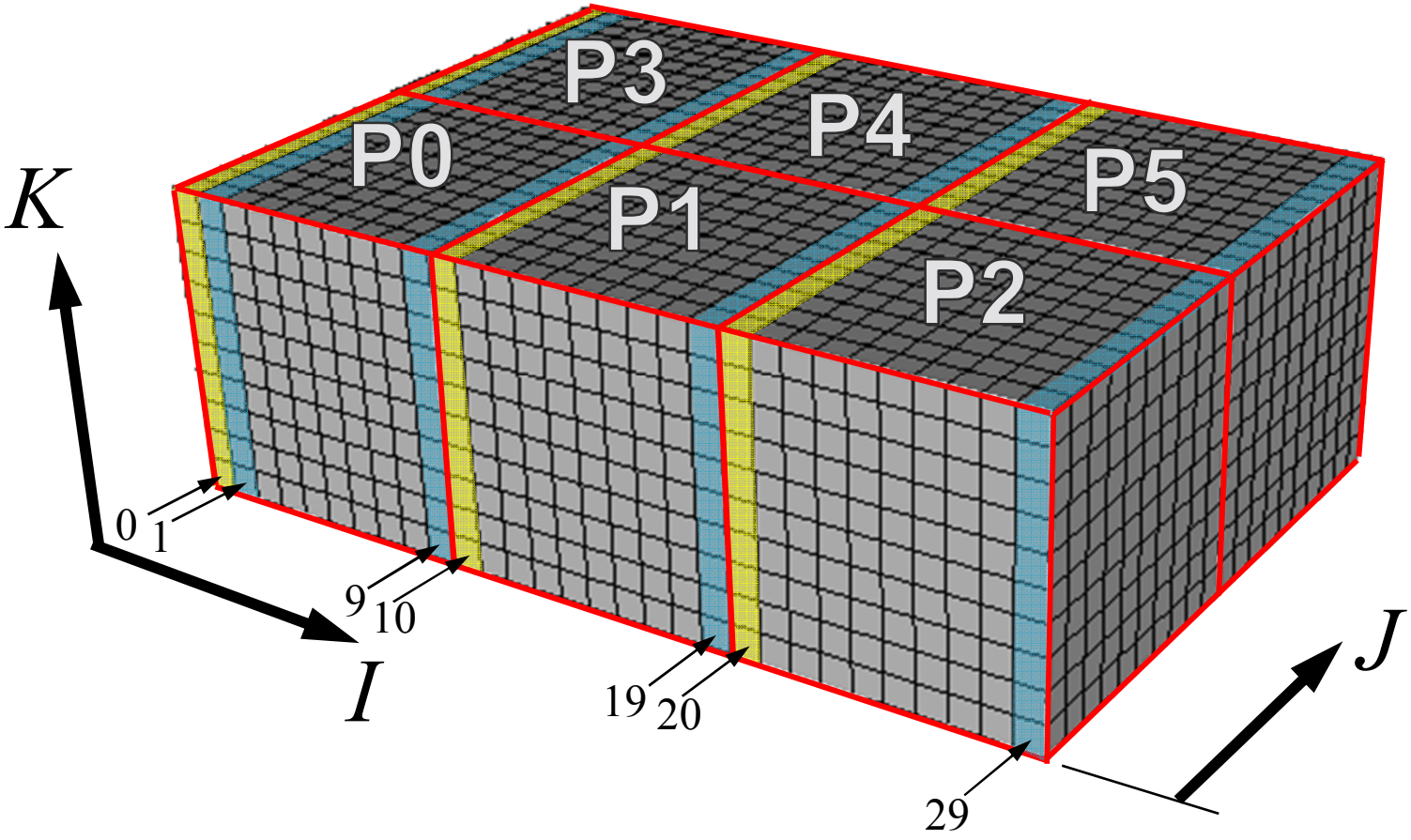

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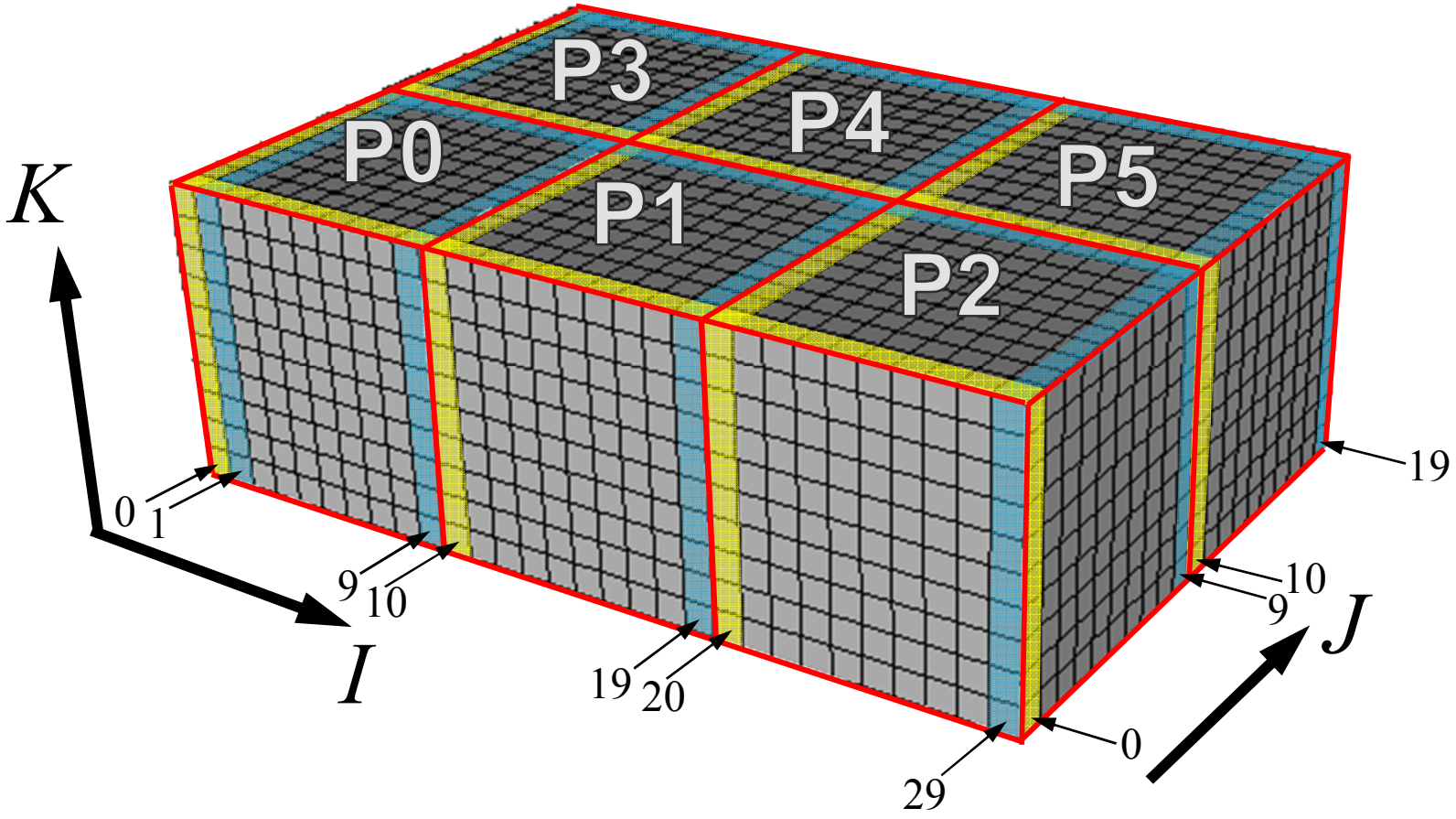

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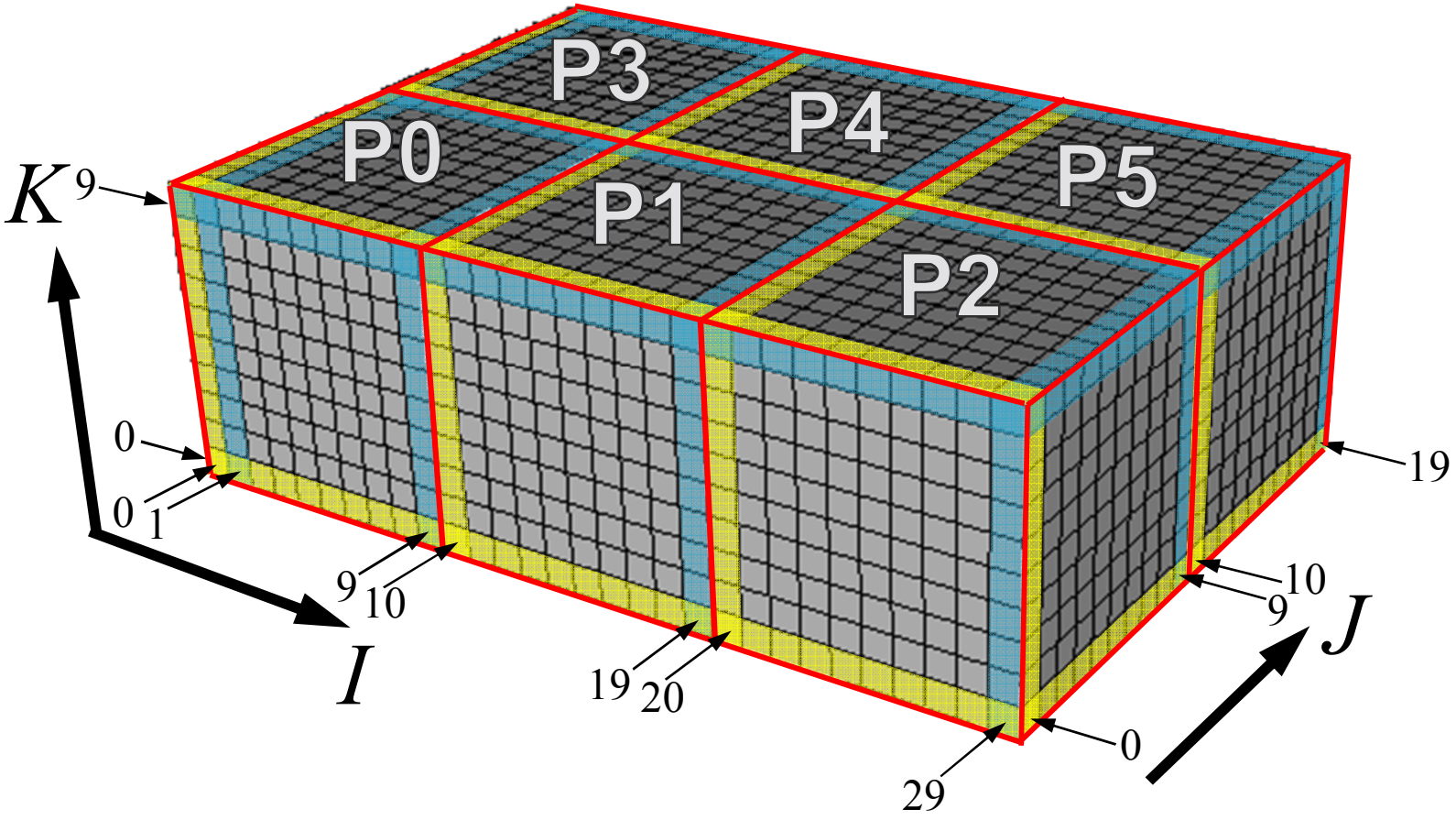

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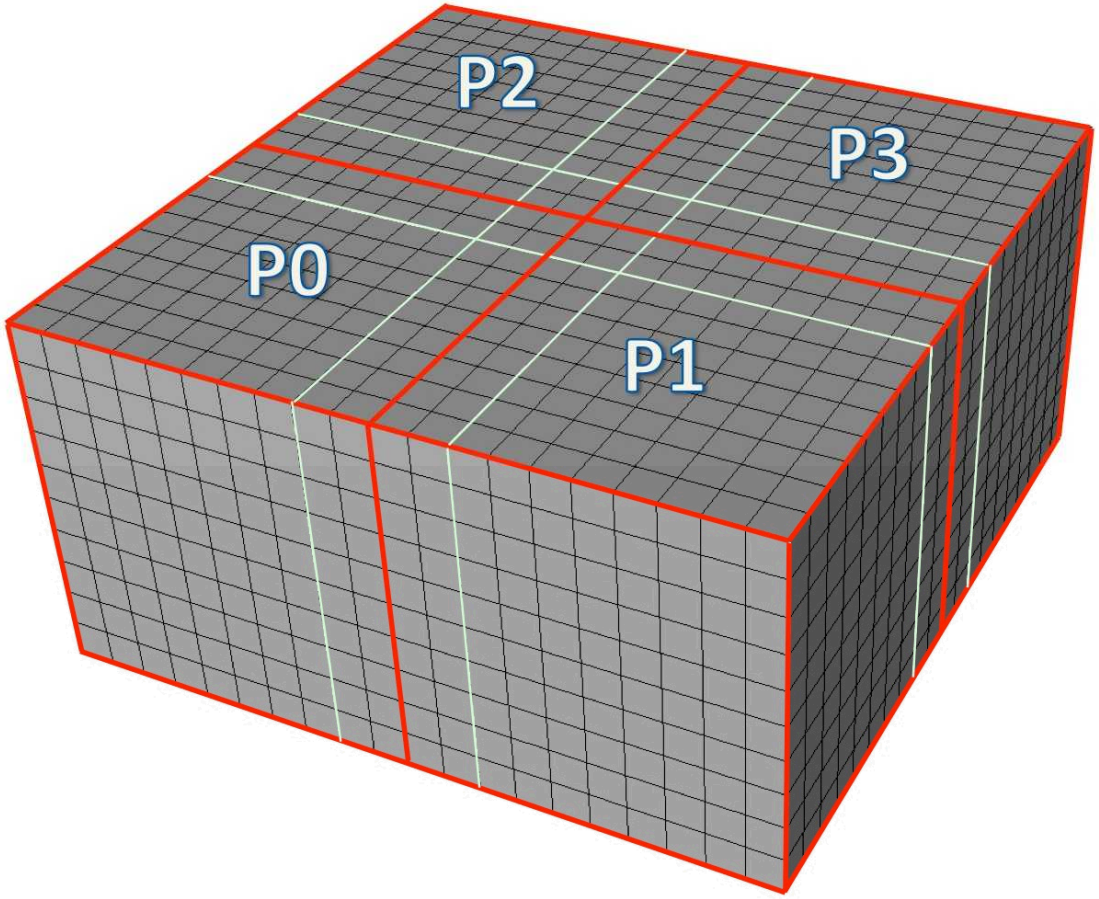

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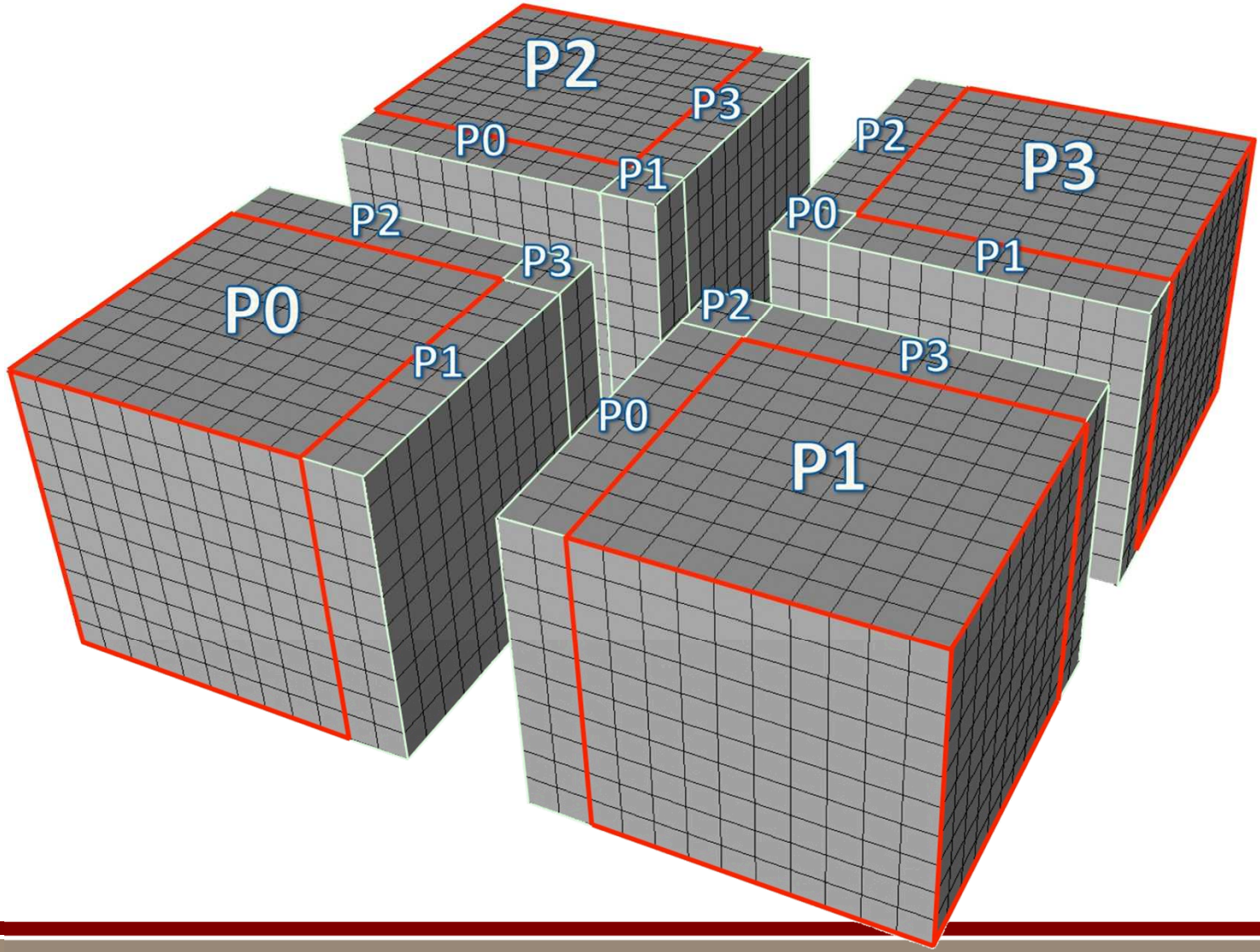

Distributed Parallel

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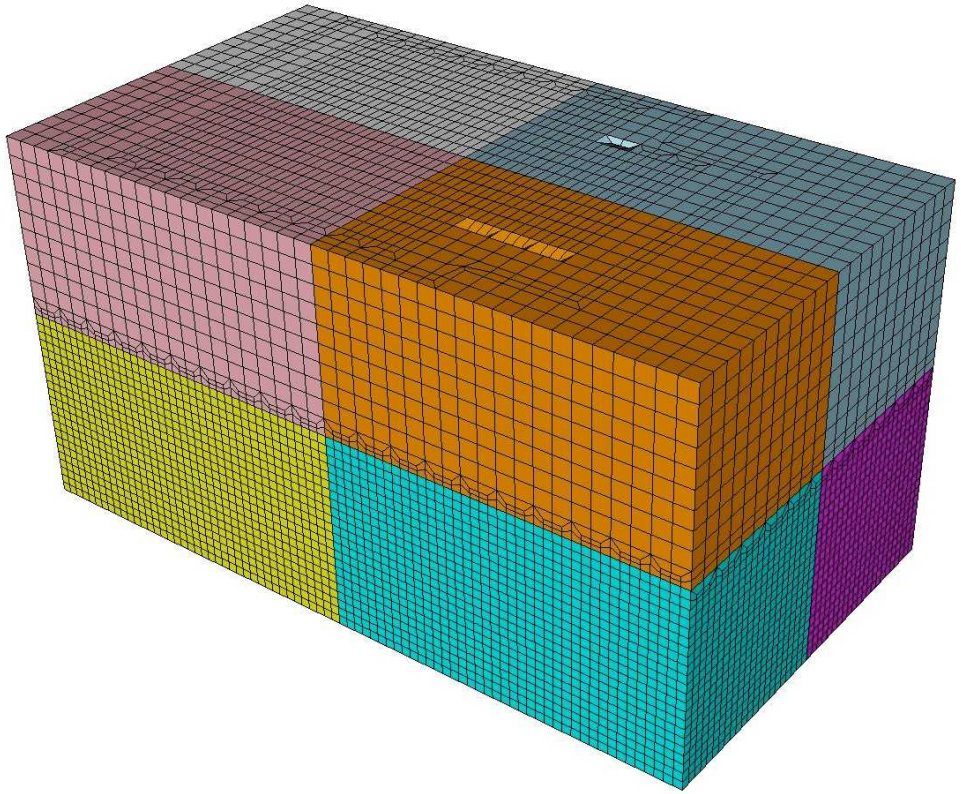

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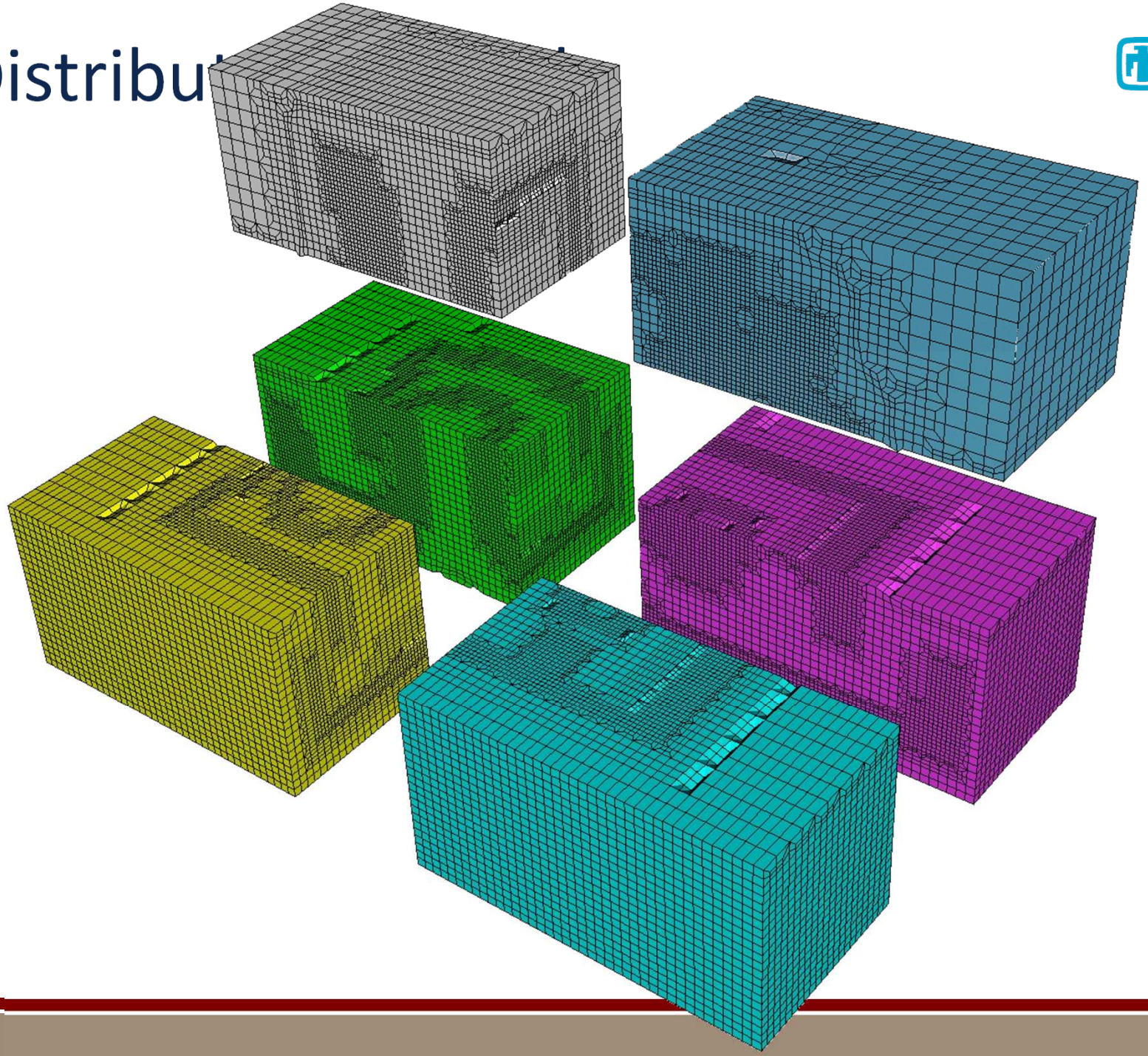

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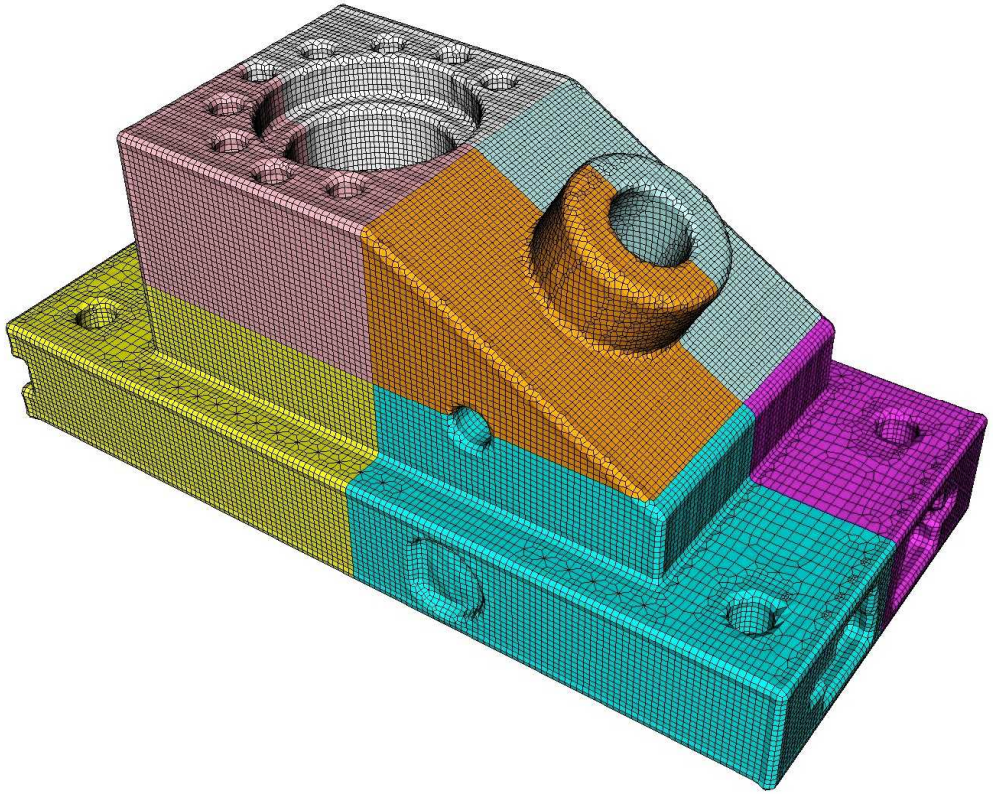

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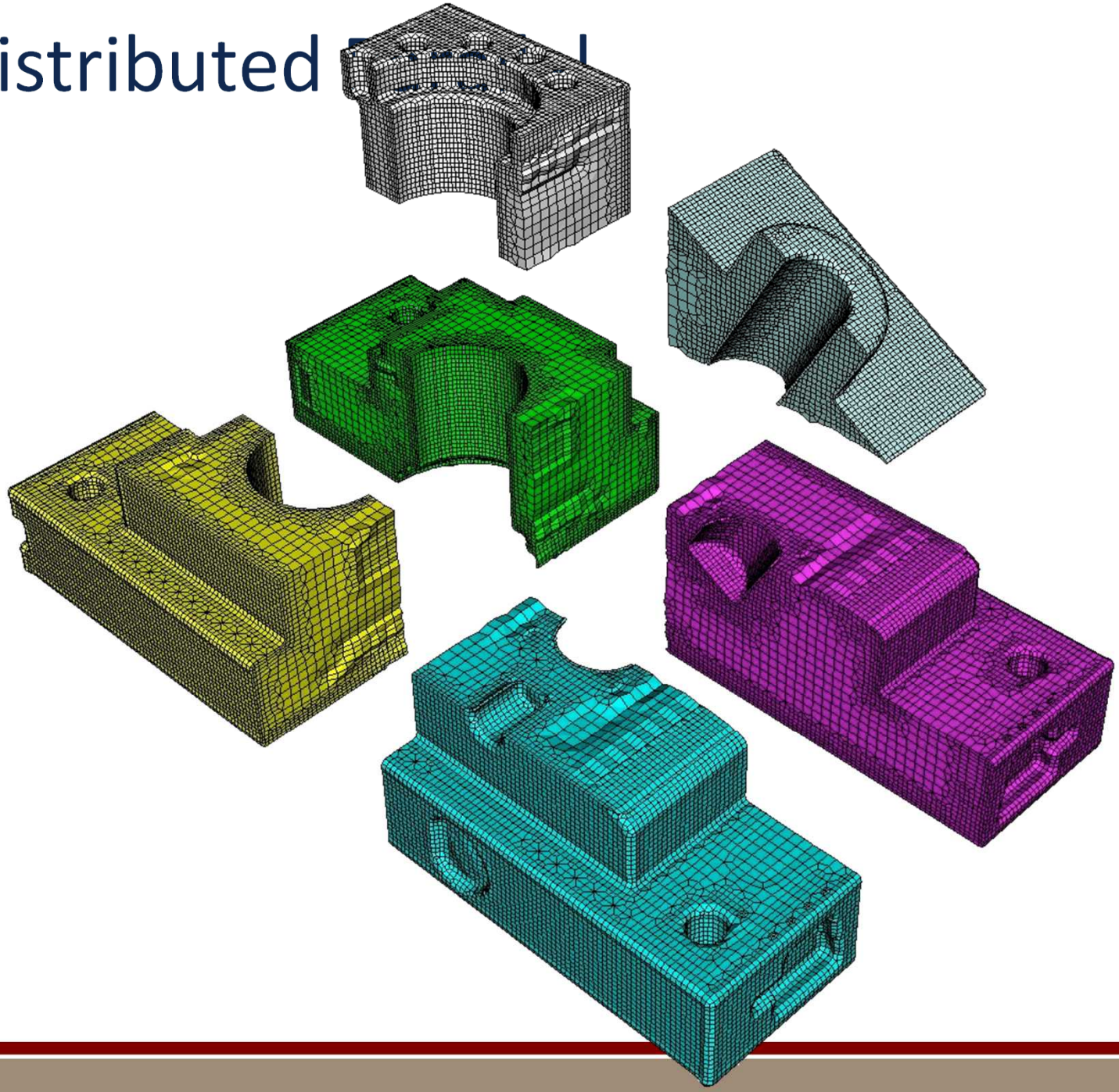
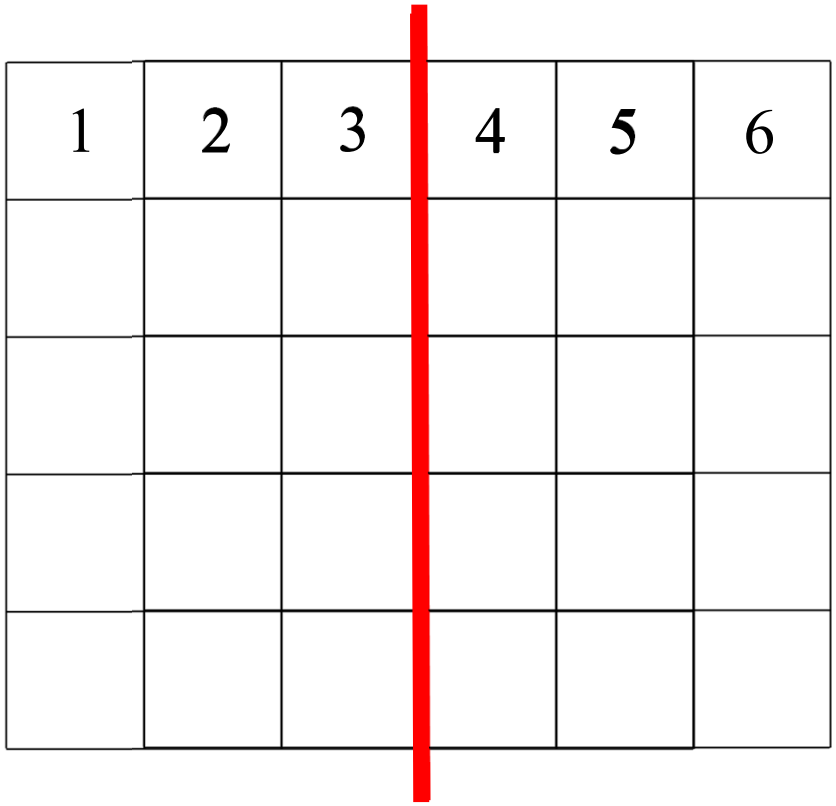


Parallel Communication



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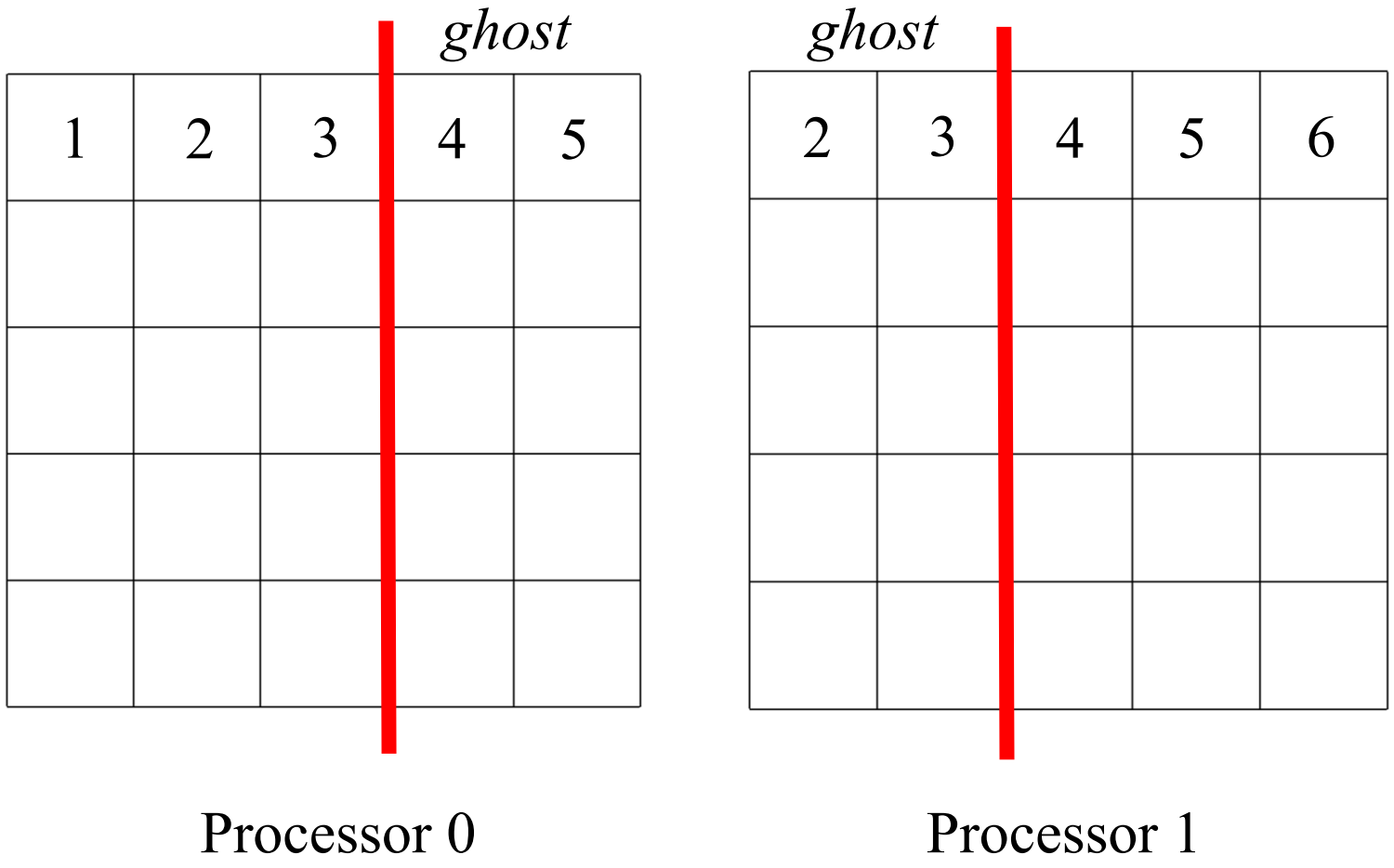

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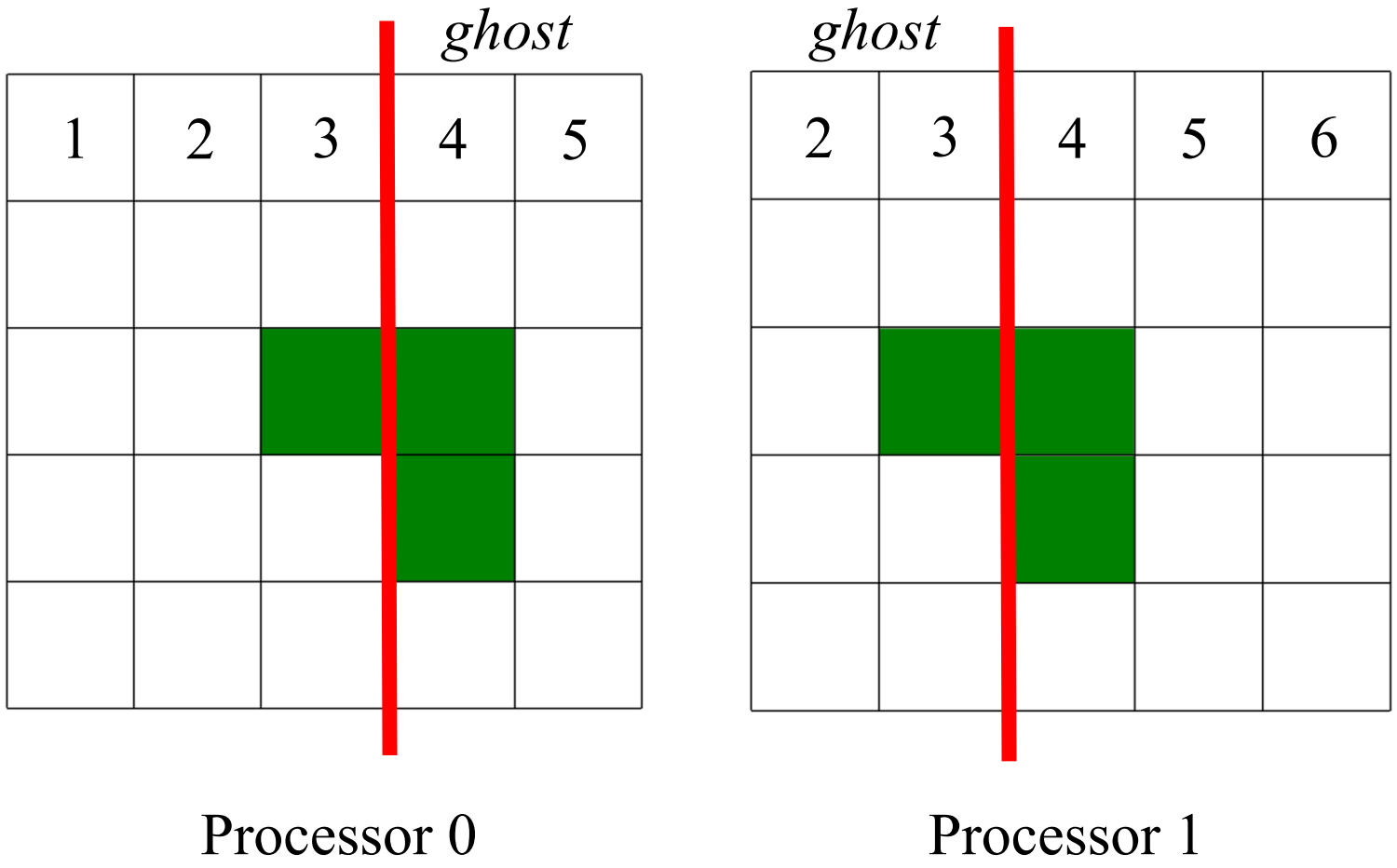

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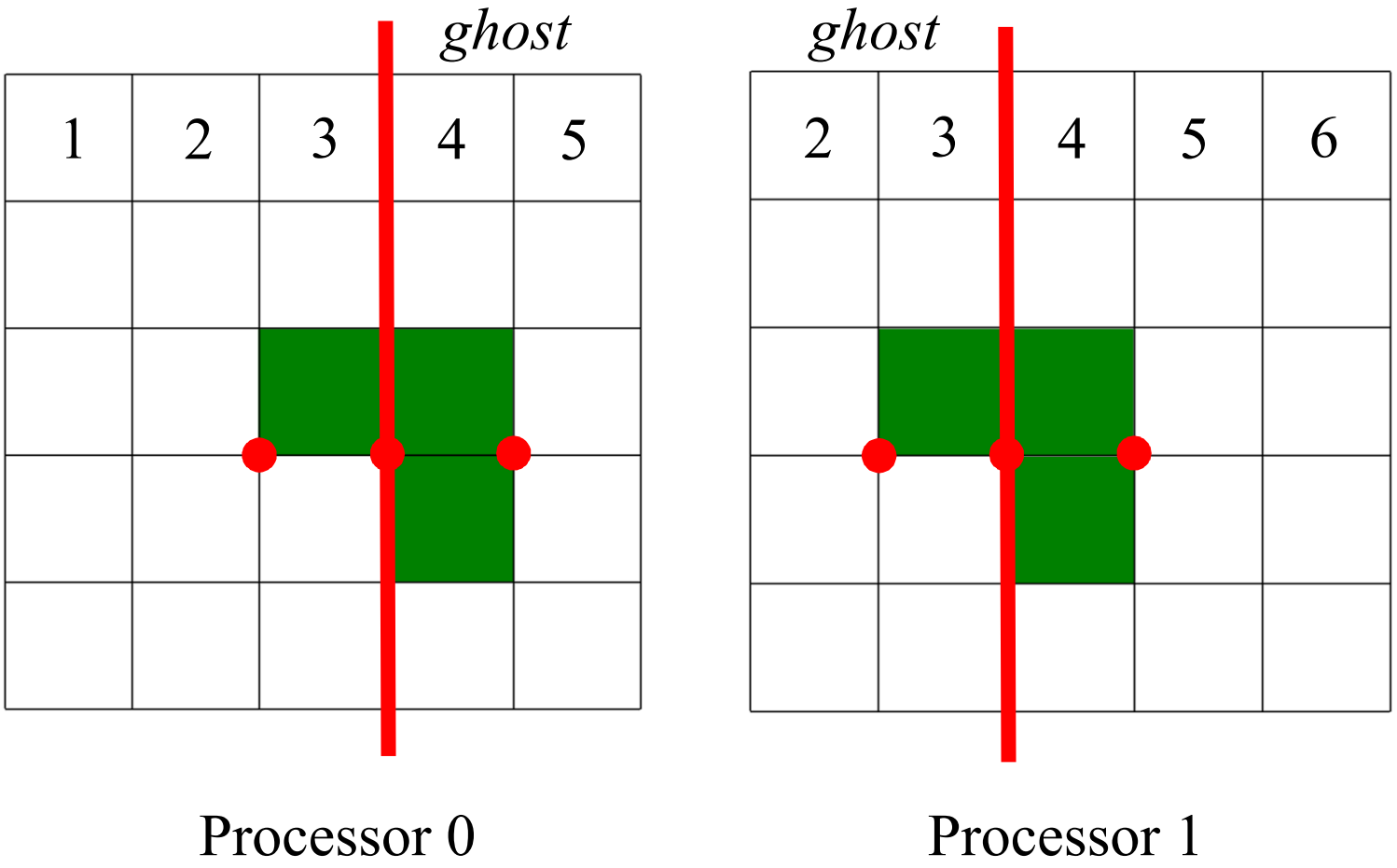

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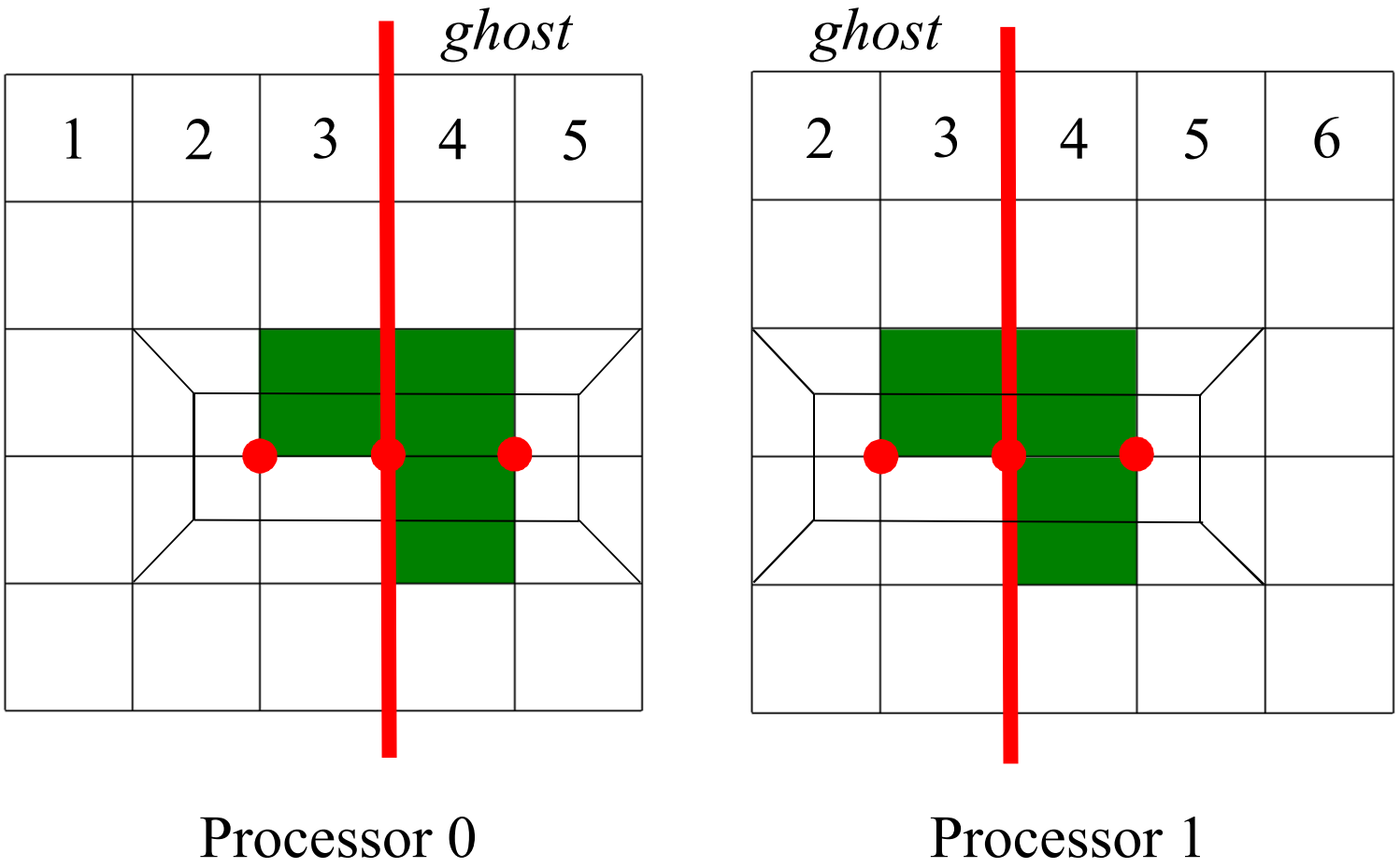

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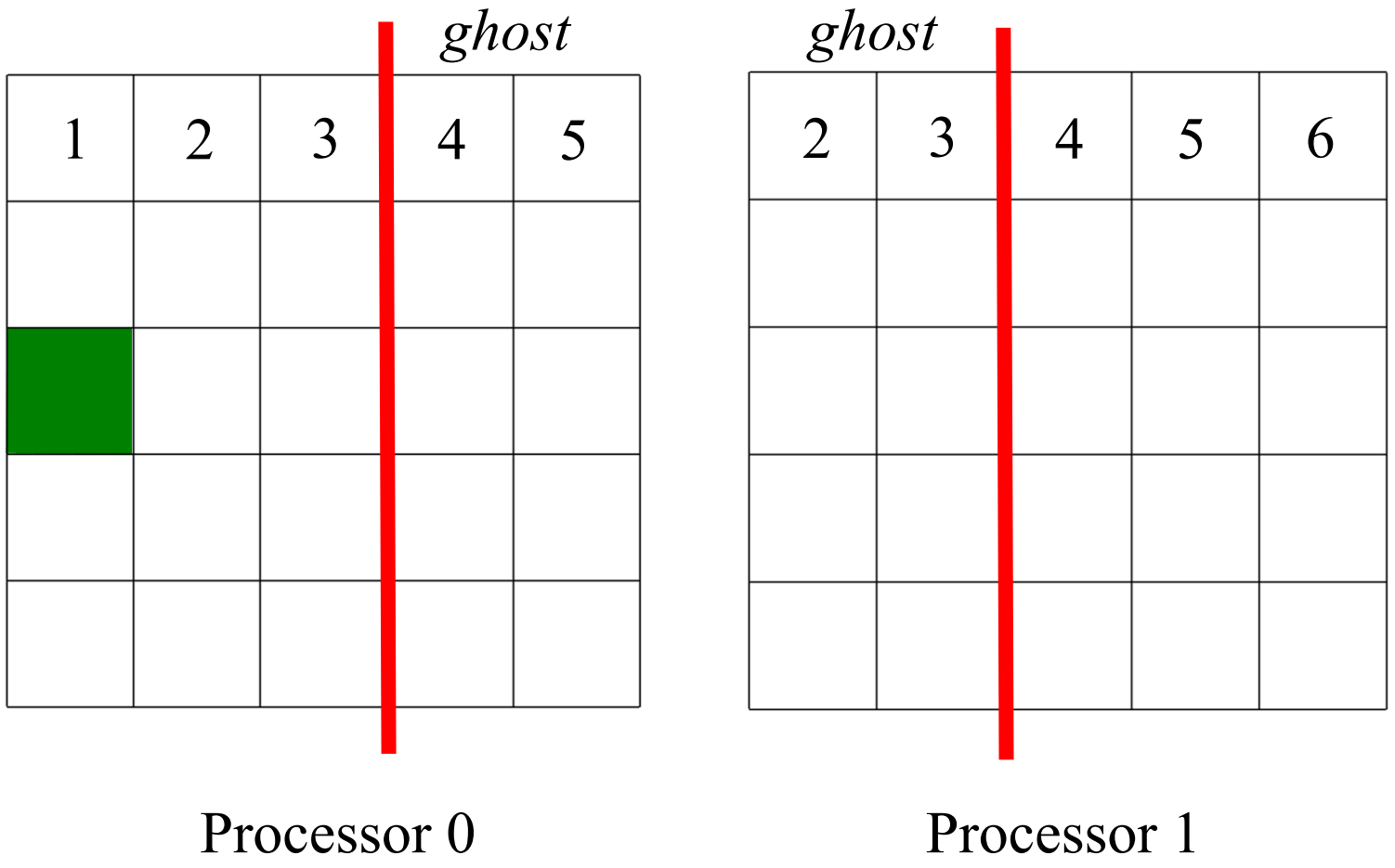

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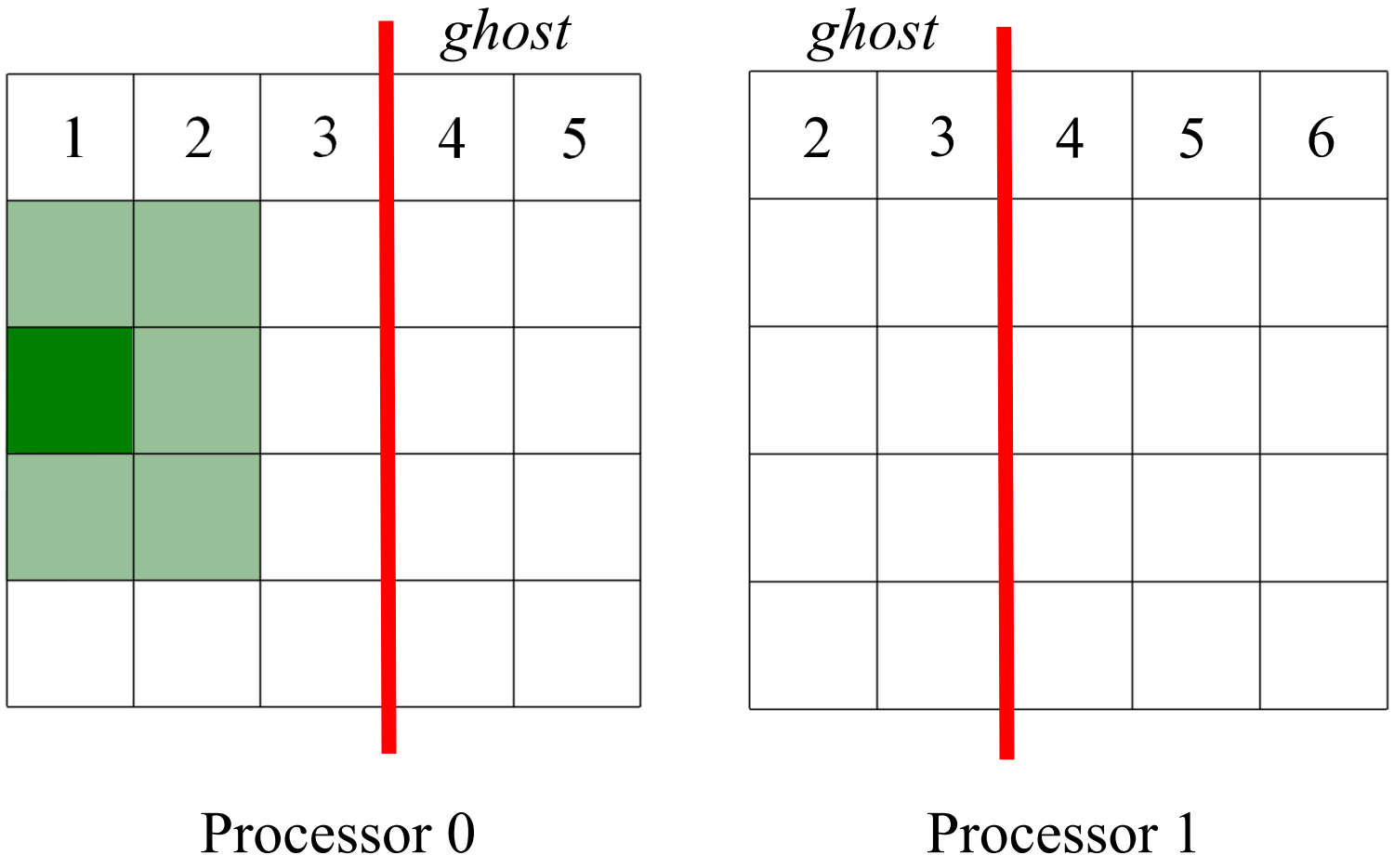

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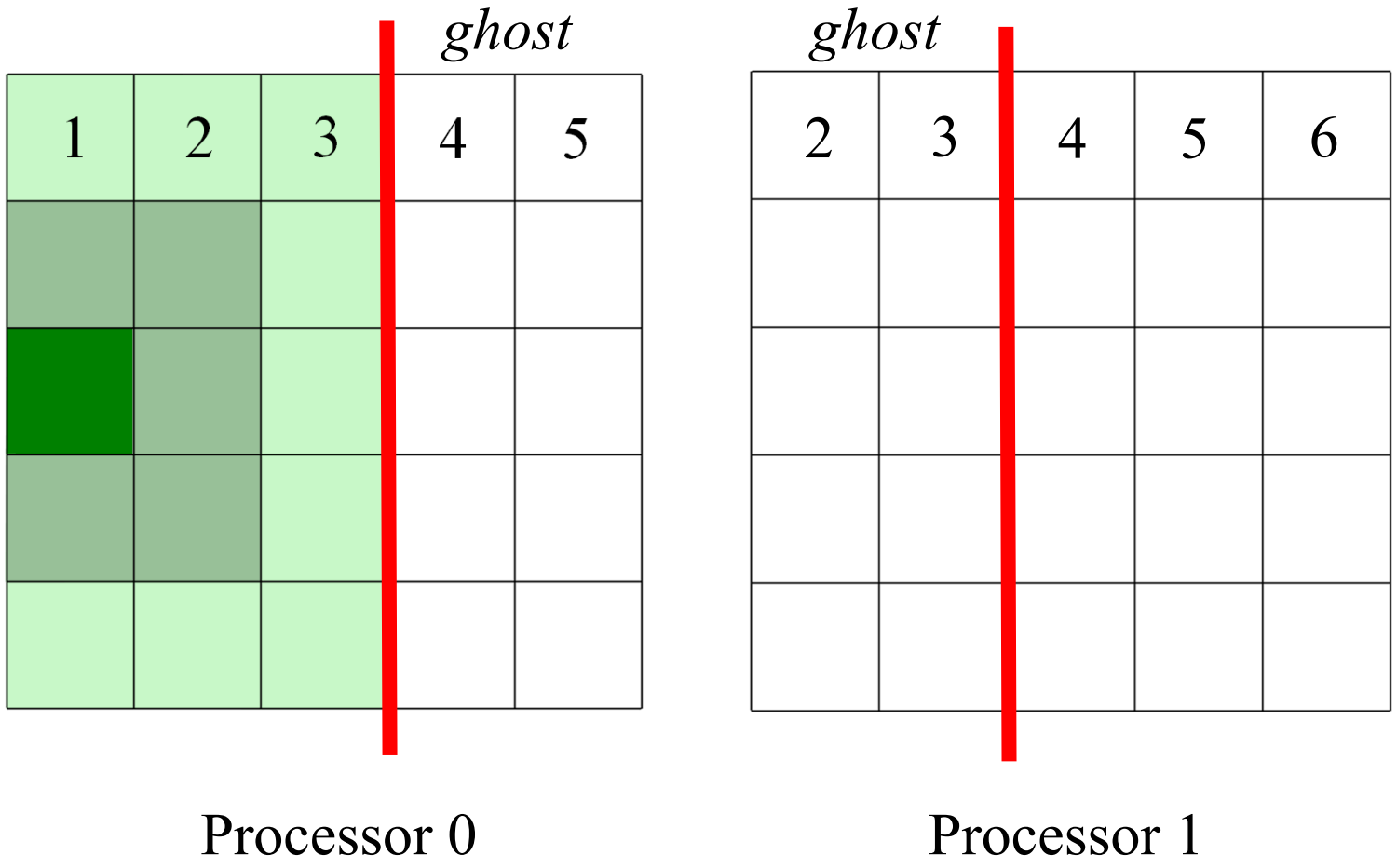

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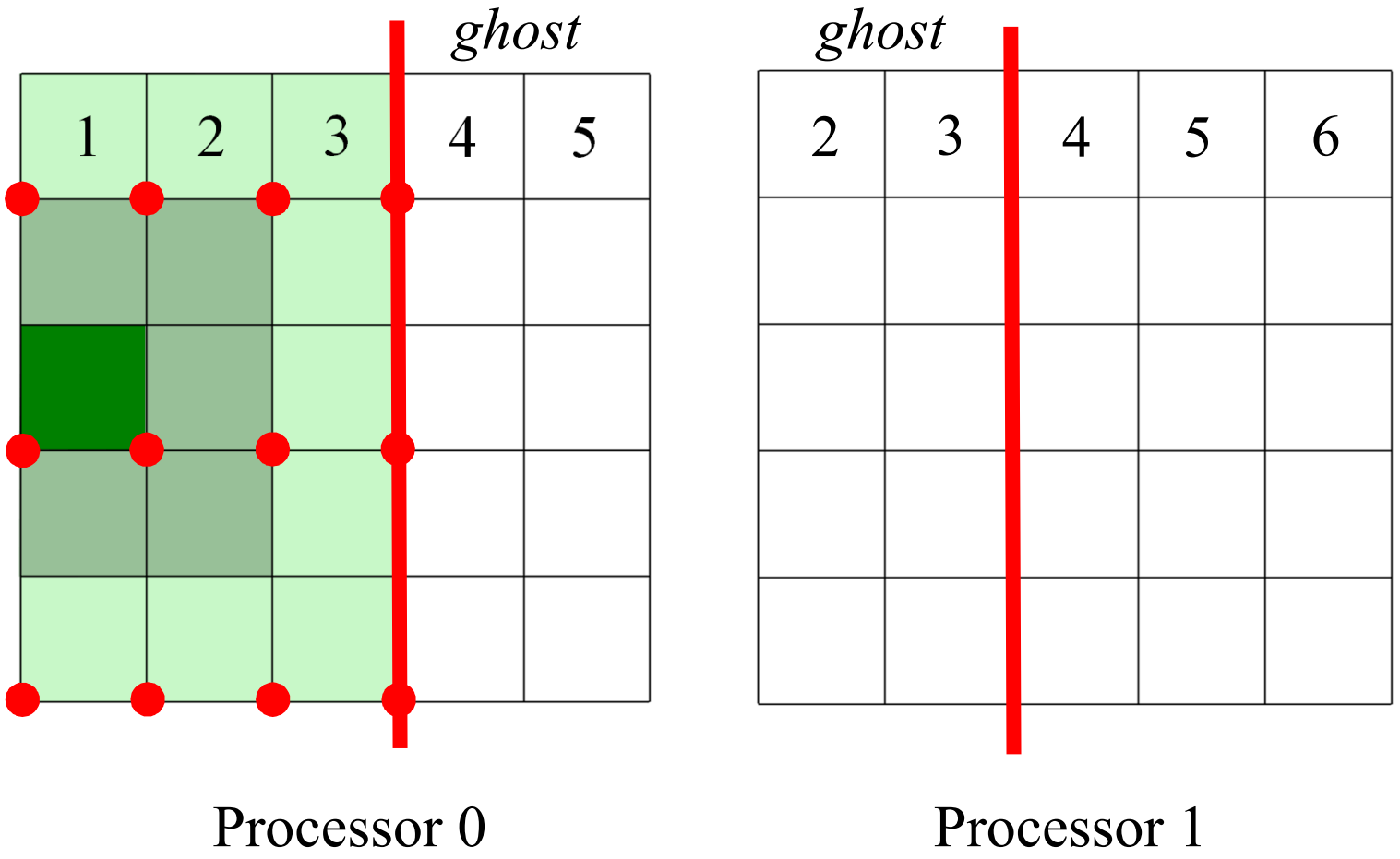

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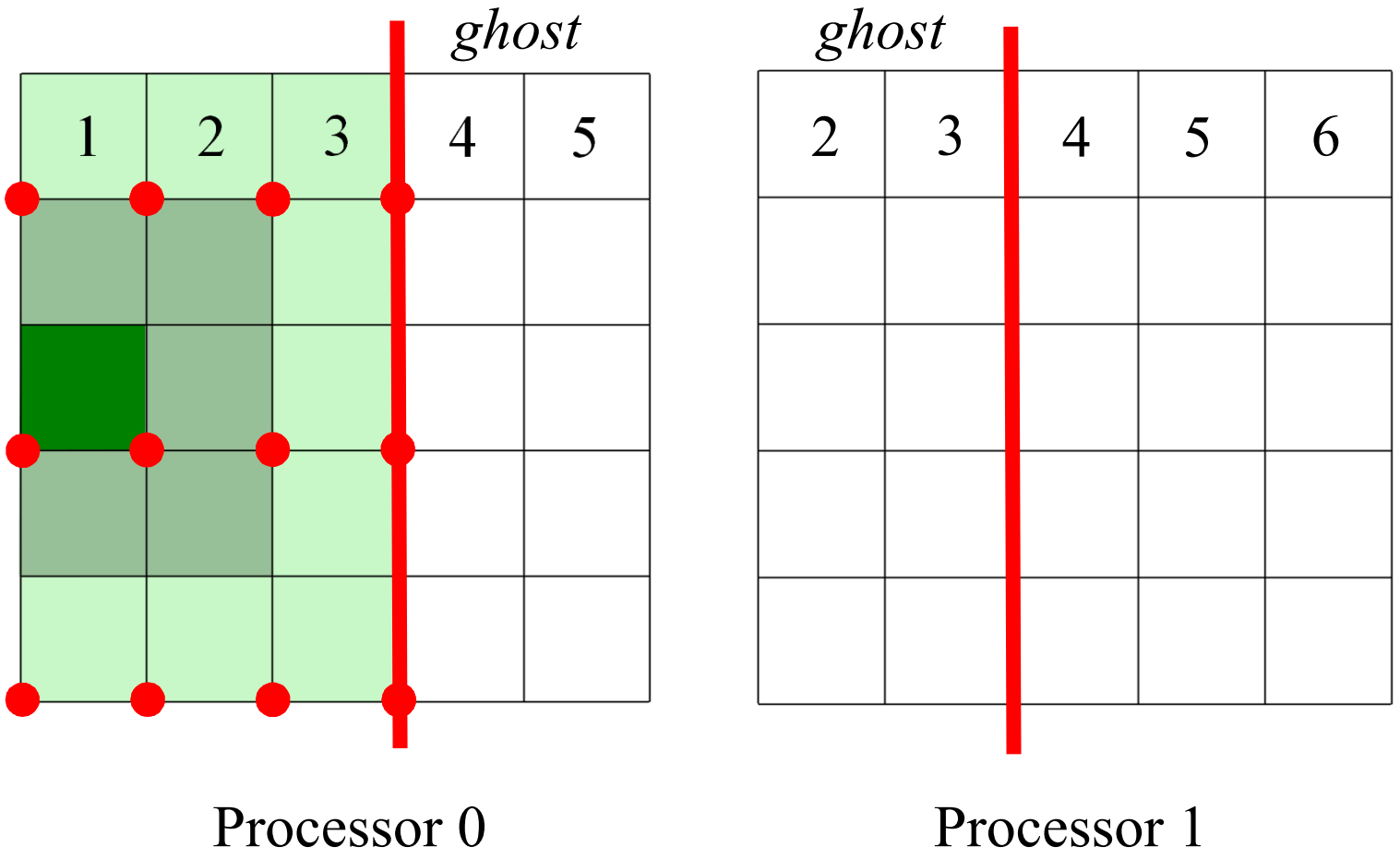

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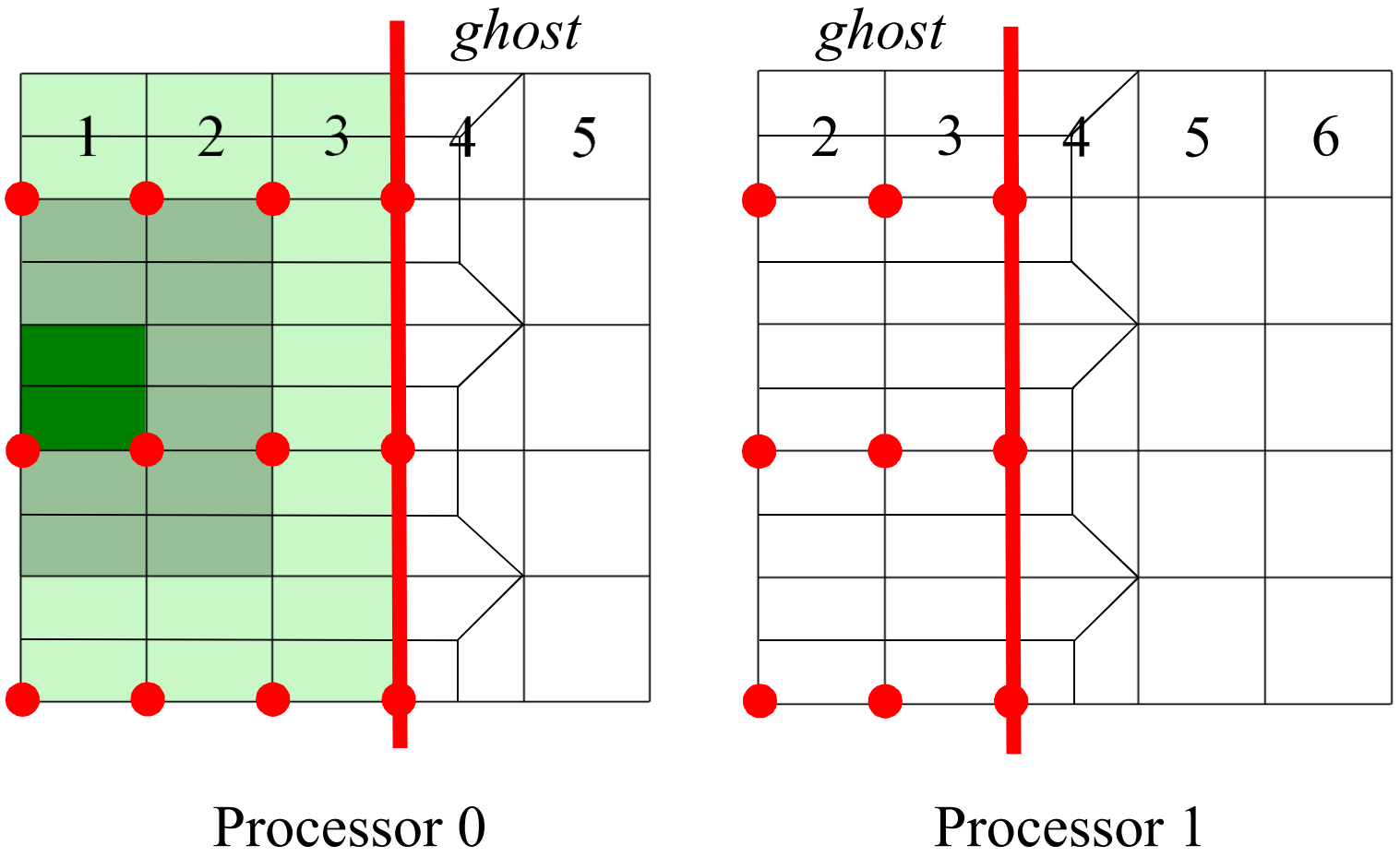

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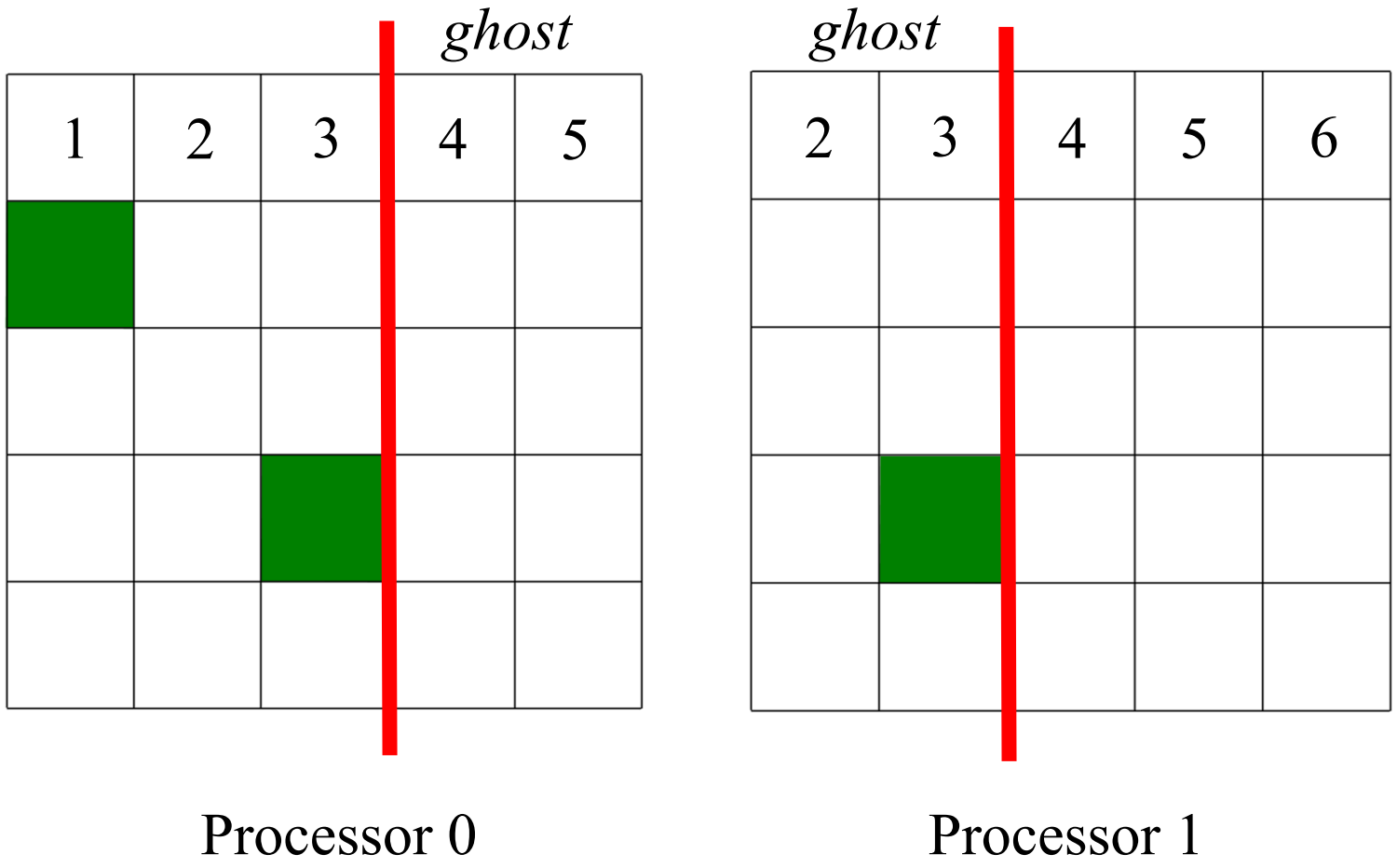

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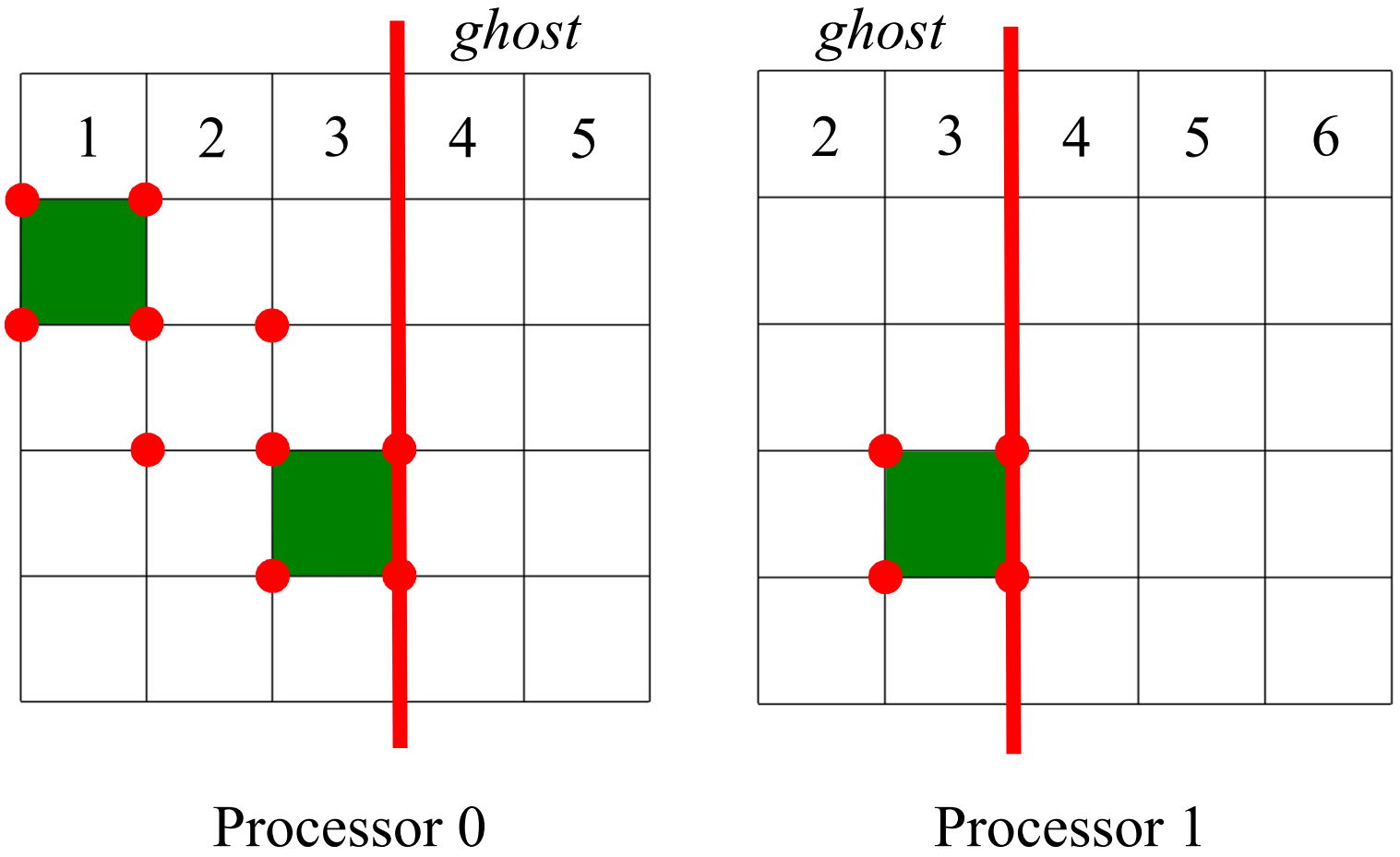

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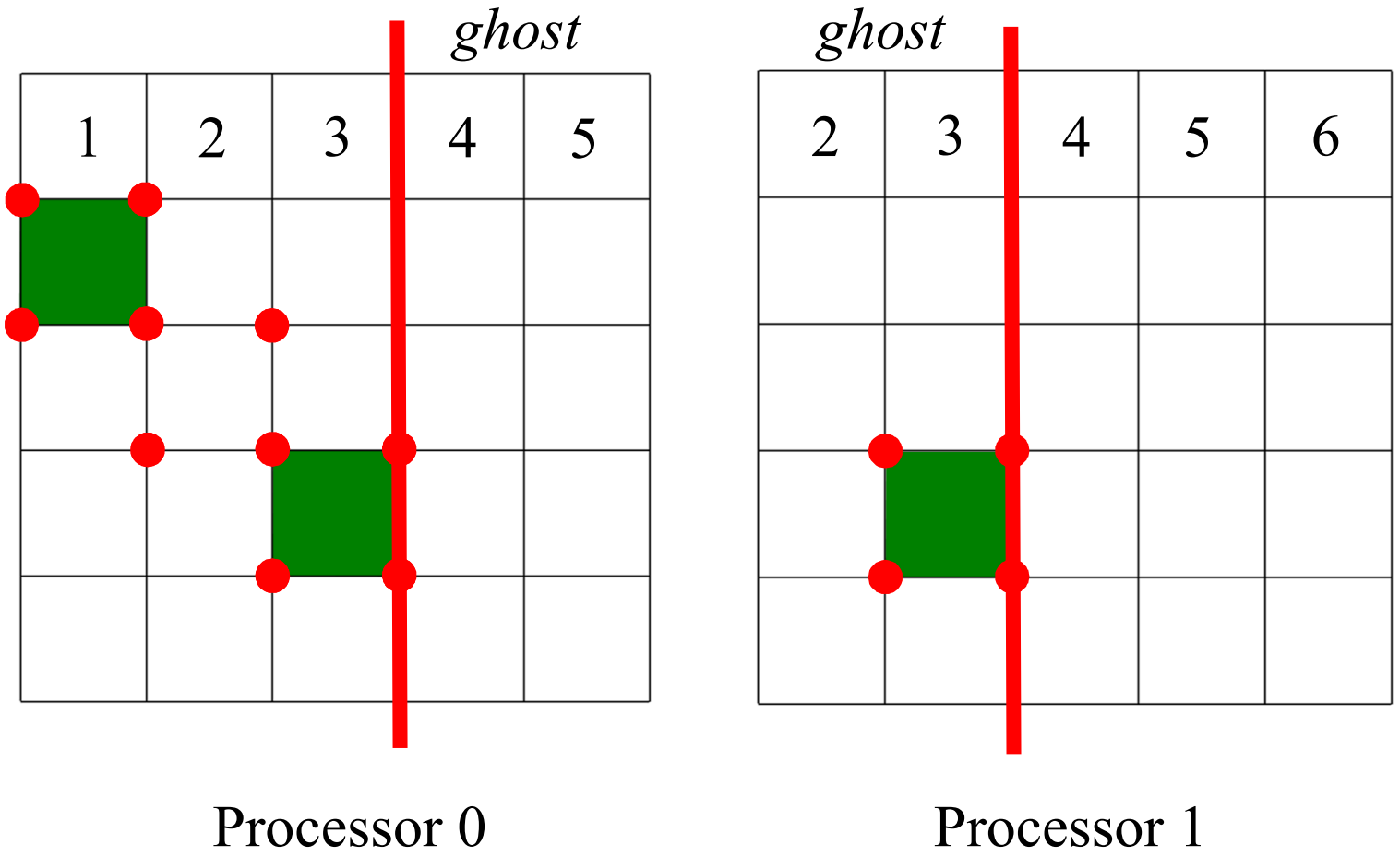

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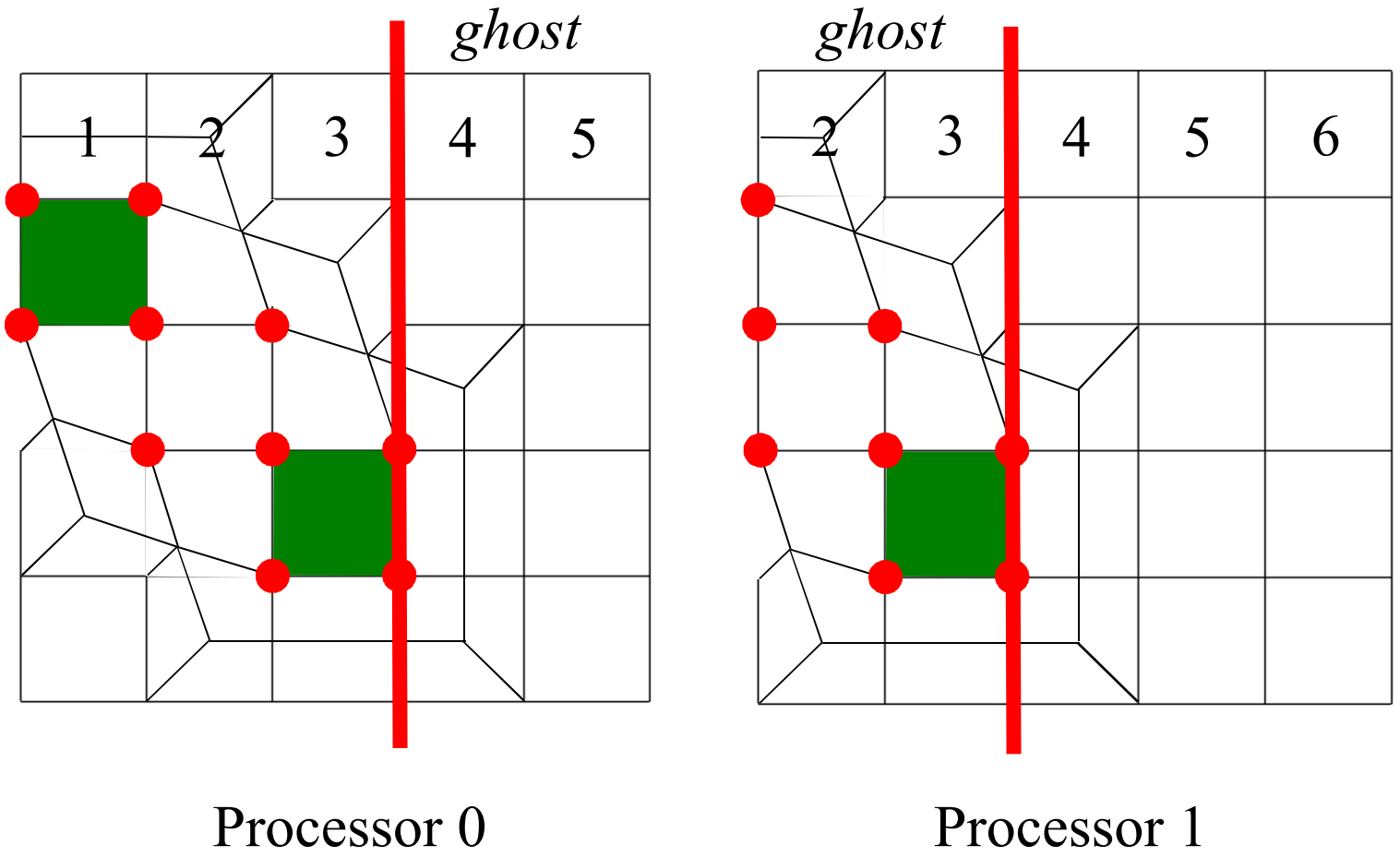

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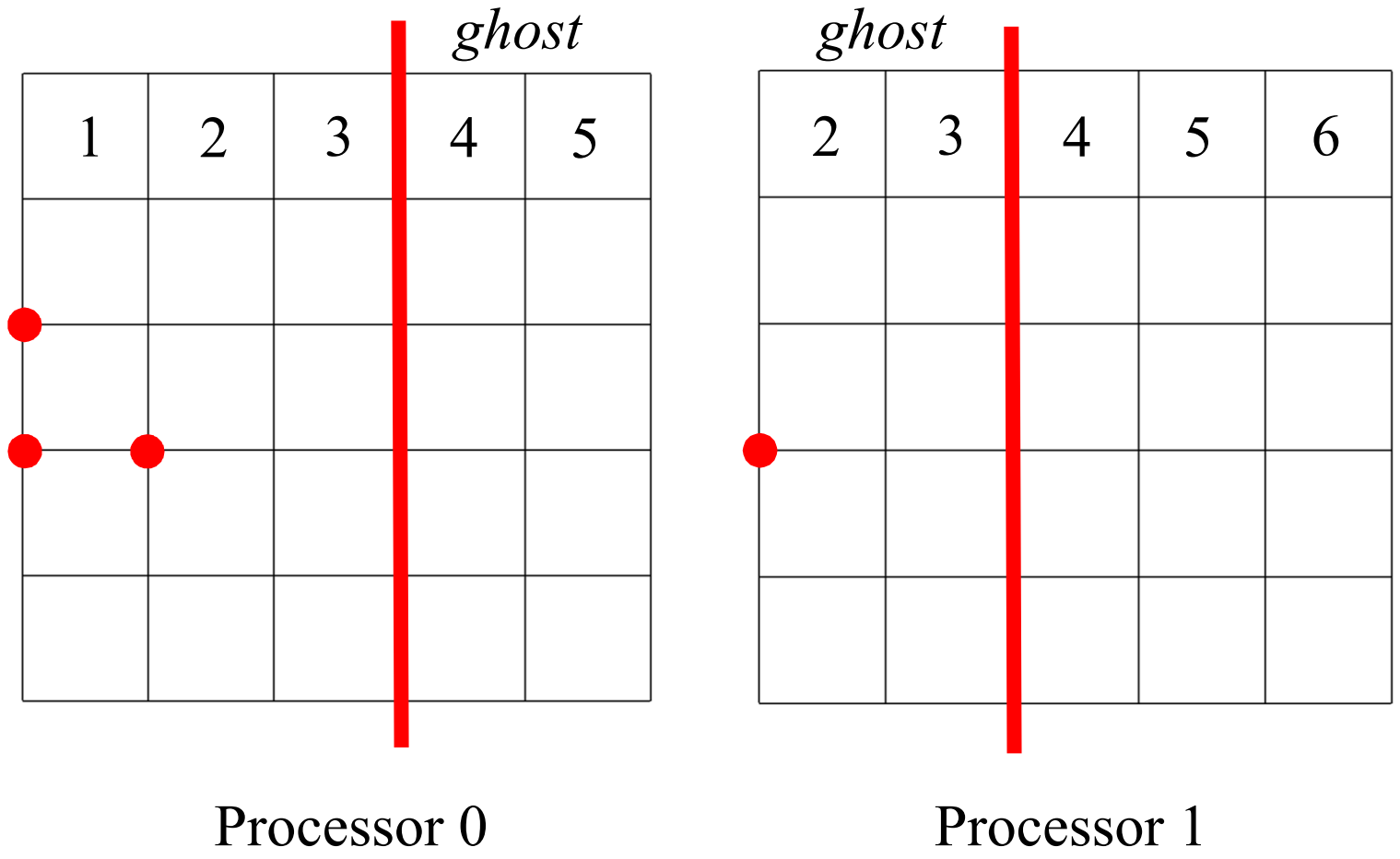

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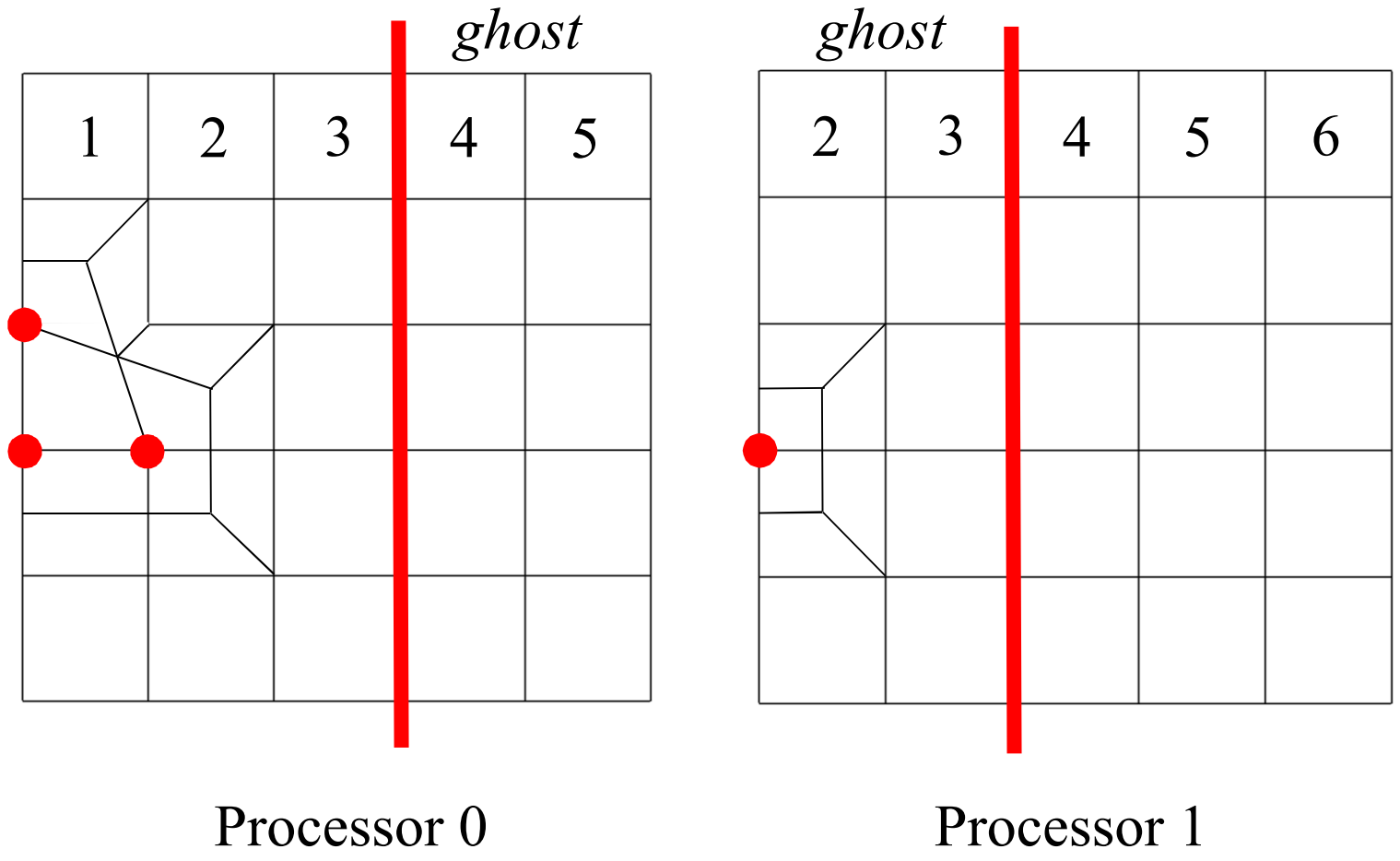

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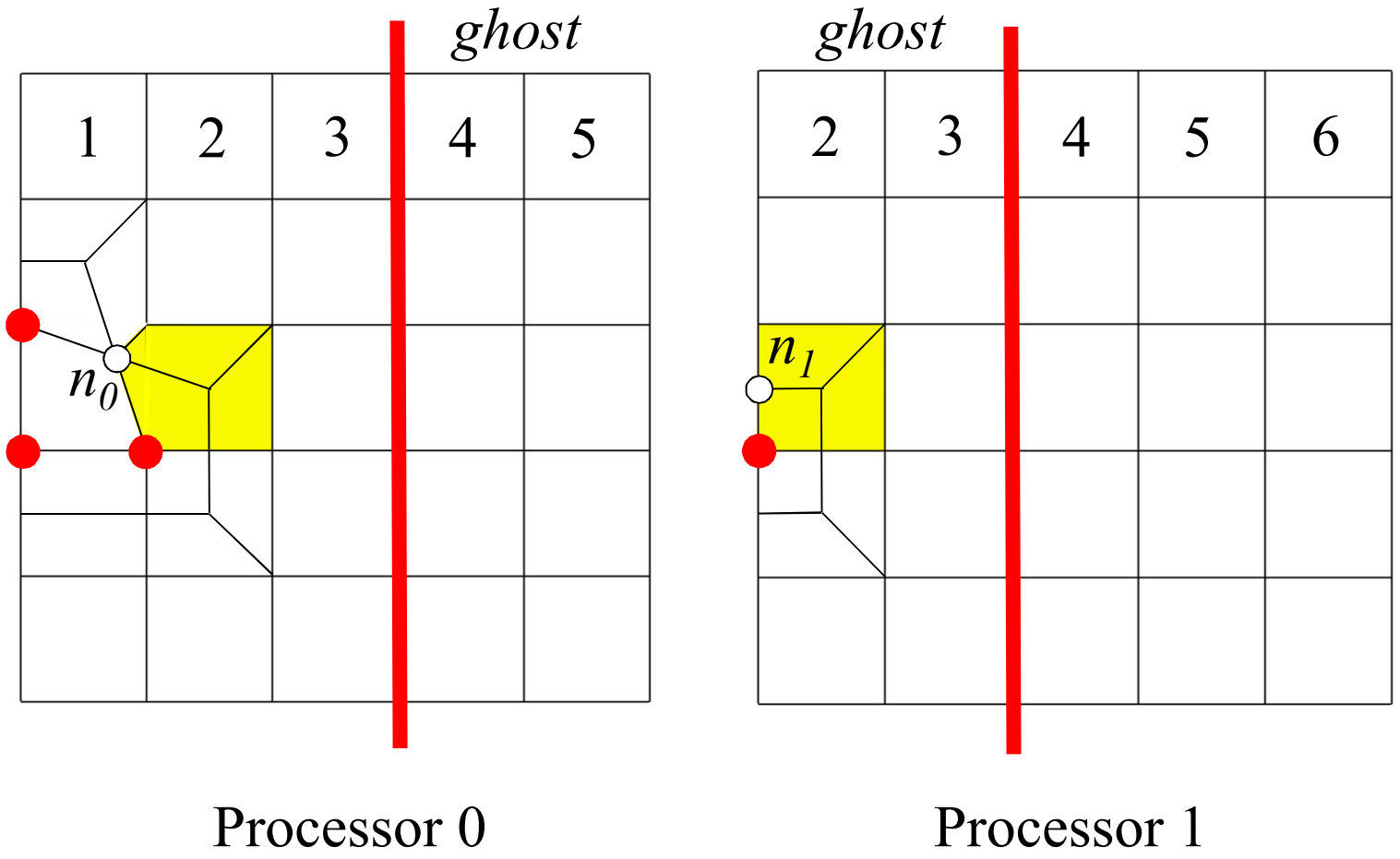
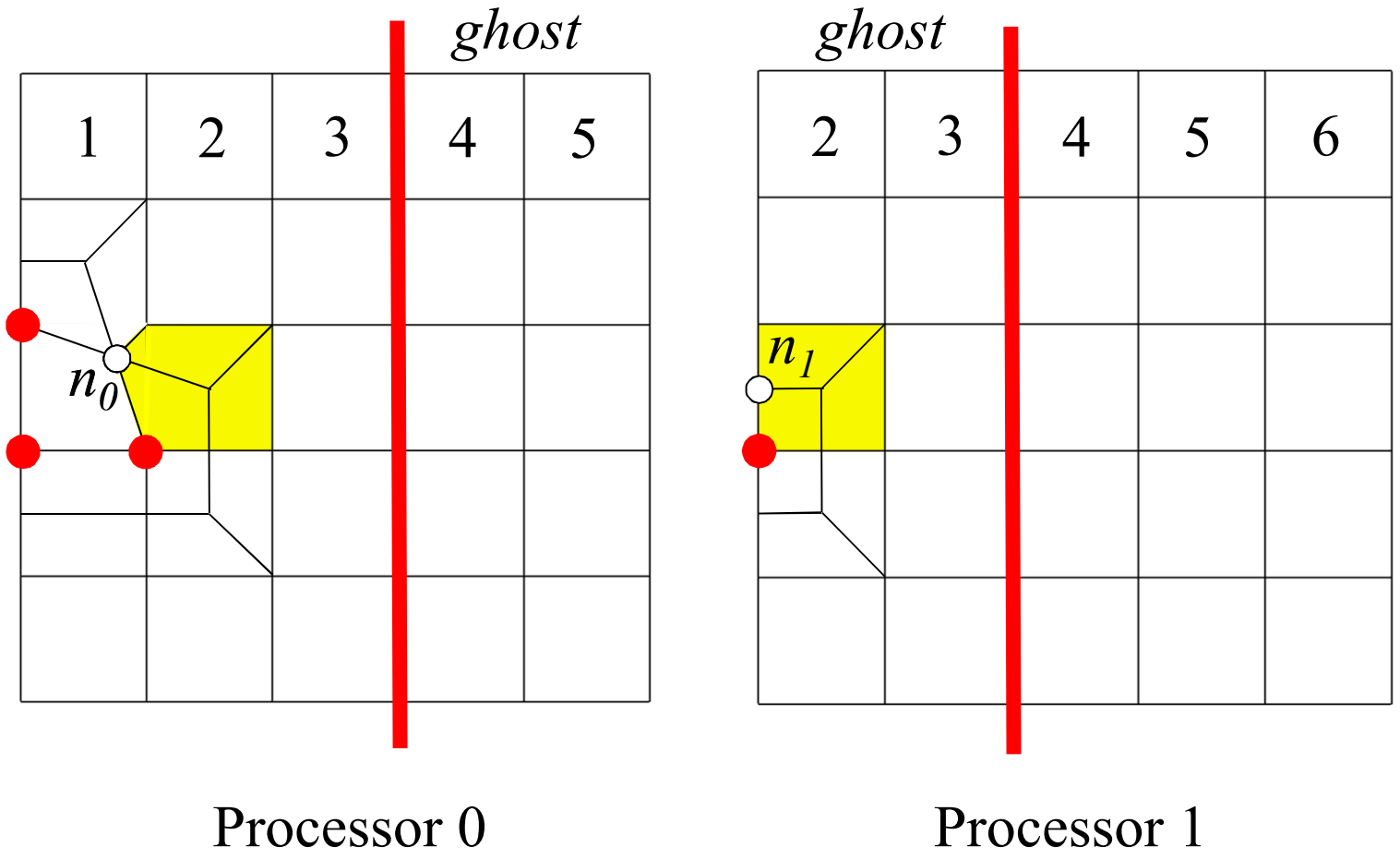
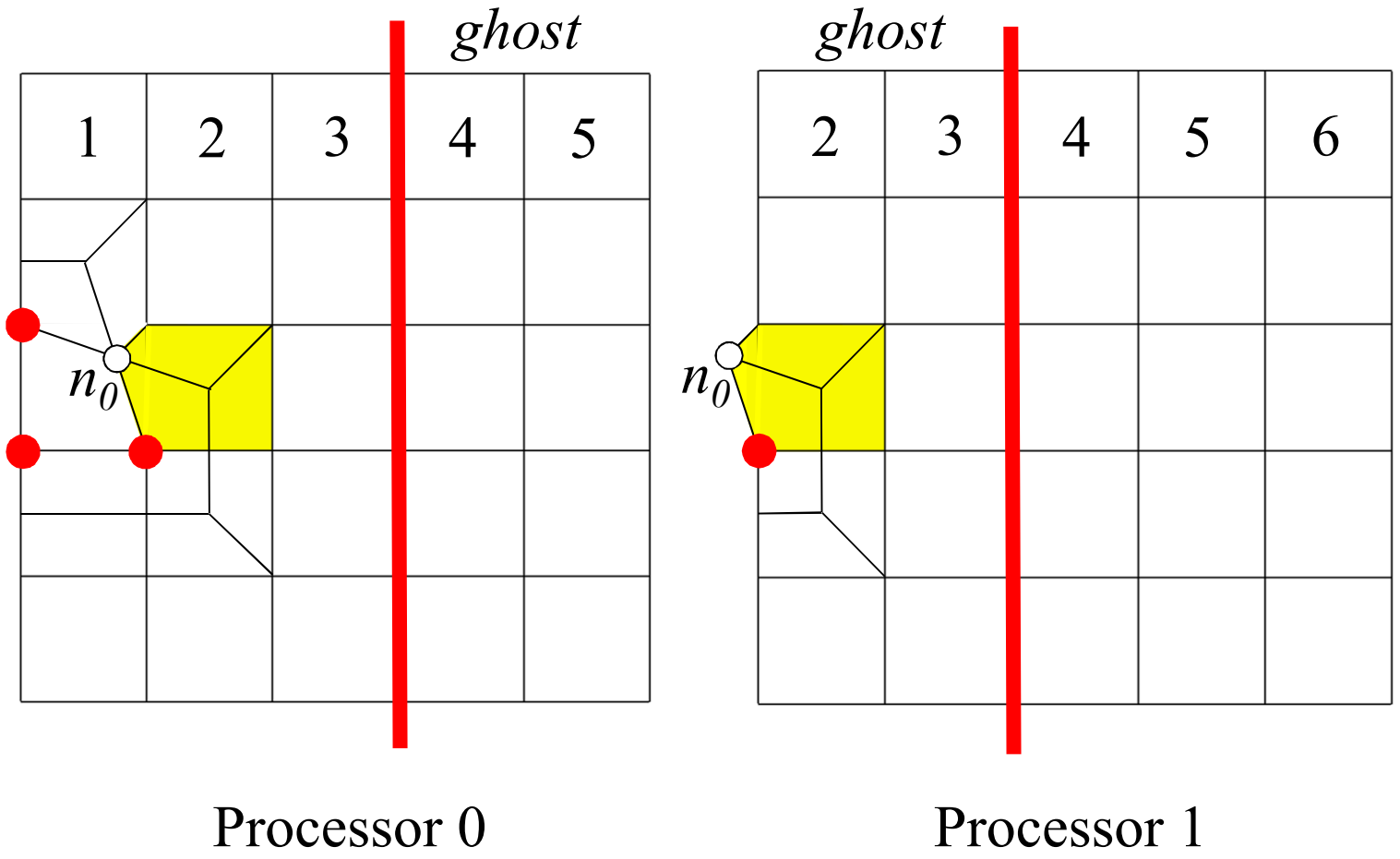


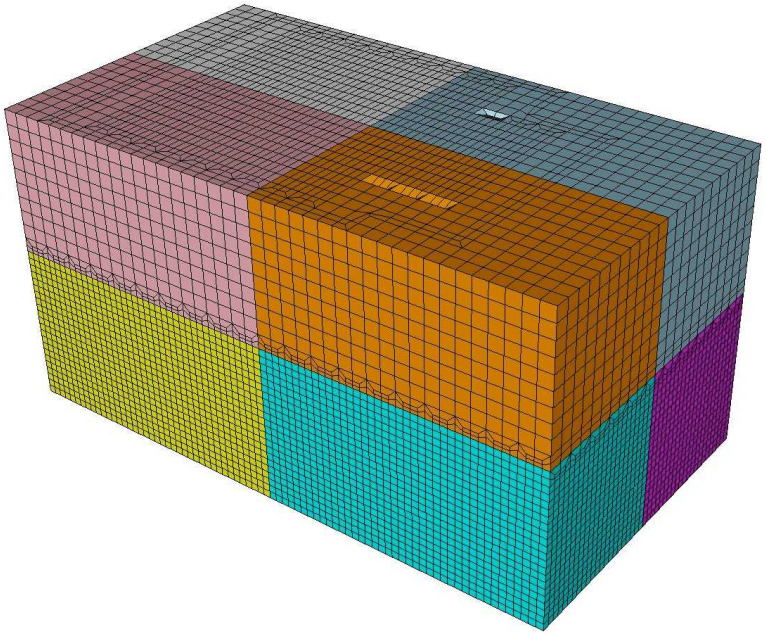
Parallel Communication

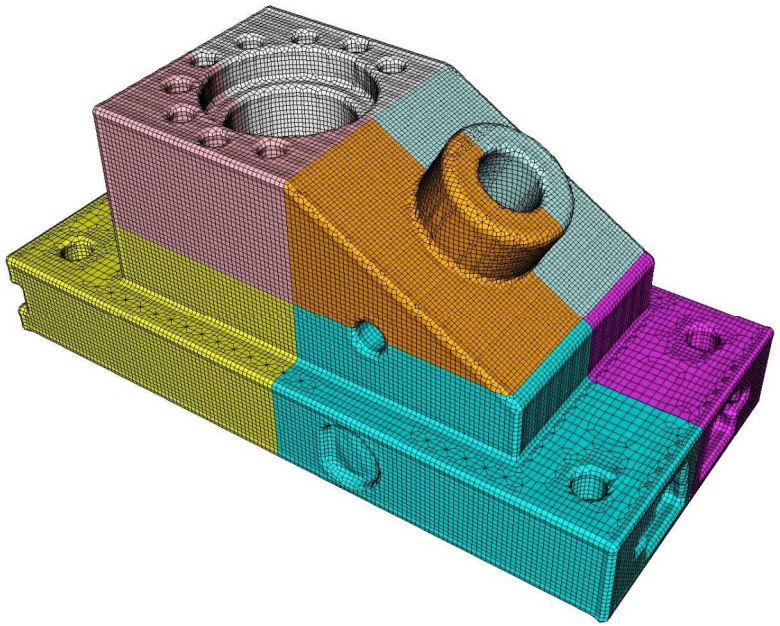


Parallel Communication



Parallel Results





	Redsky 519/4,152 nodes/cores 2.93GHz Intel, 12GB/node	Chama 1,232/19,712 nodes/cores 2.6GHz Intel, 64GB/node
Initial Hexes in Cartesian Grid	32,400	498,960
Hexes in Refined Grid	730,512	4,750,848
Minimum Scaled Jacobian	0.408	0.408

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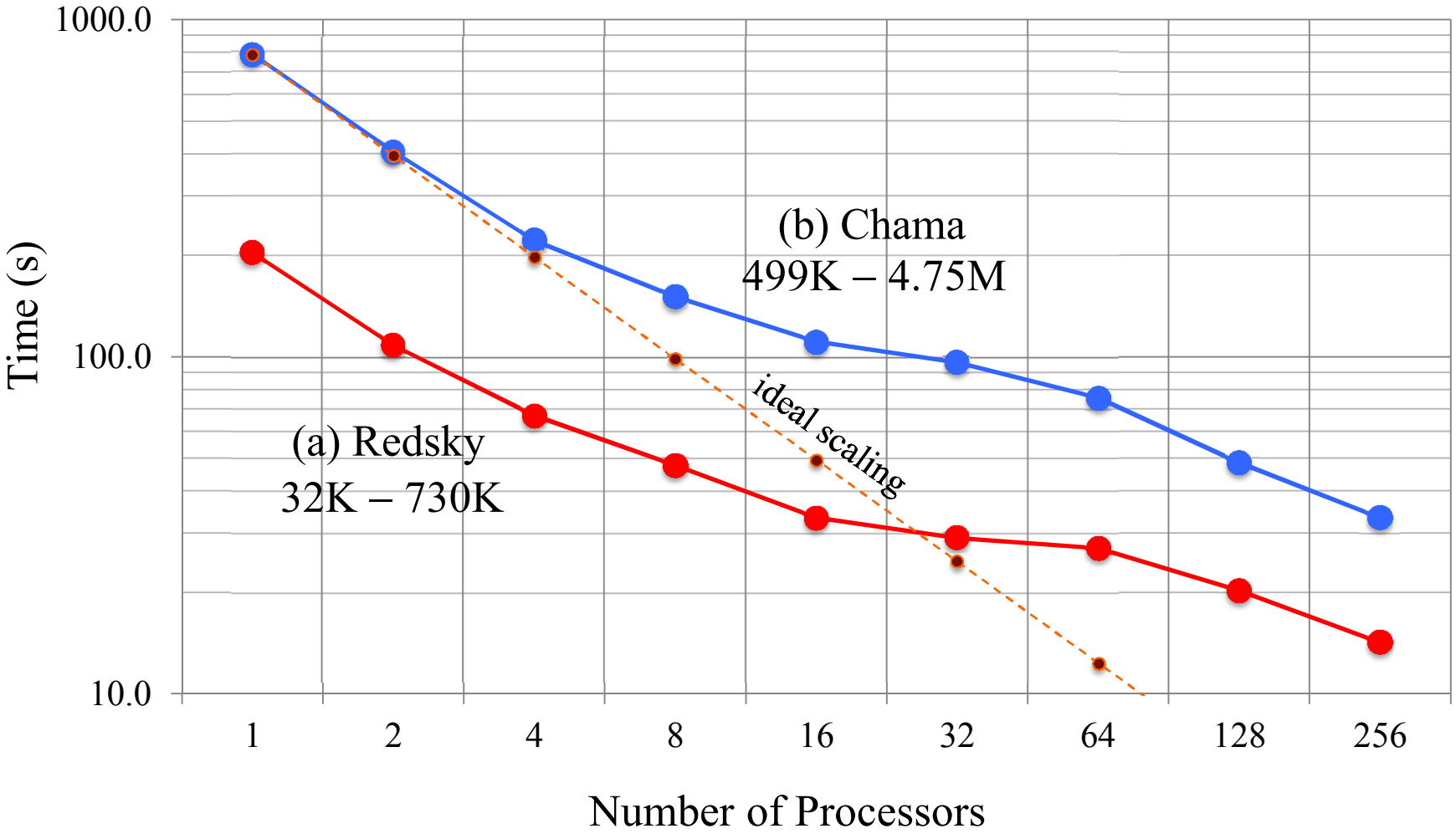
Time to Refine model anc101



Conclusions

- 2-Refinement based on node marking procedure and 4 templates (3D)
- Uses up to 3 layers to transition
- Minimum Scaled Jacobian 0.408
- Distributed Parallel Implementation with Sculpt
- Parallel-consistent (Same result regardless of decomposition)
- Multiple levels of refinement