GENERATING ADAPTIVE DISTANCE FIELDS FROM TRIANGLE MESHES

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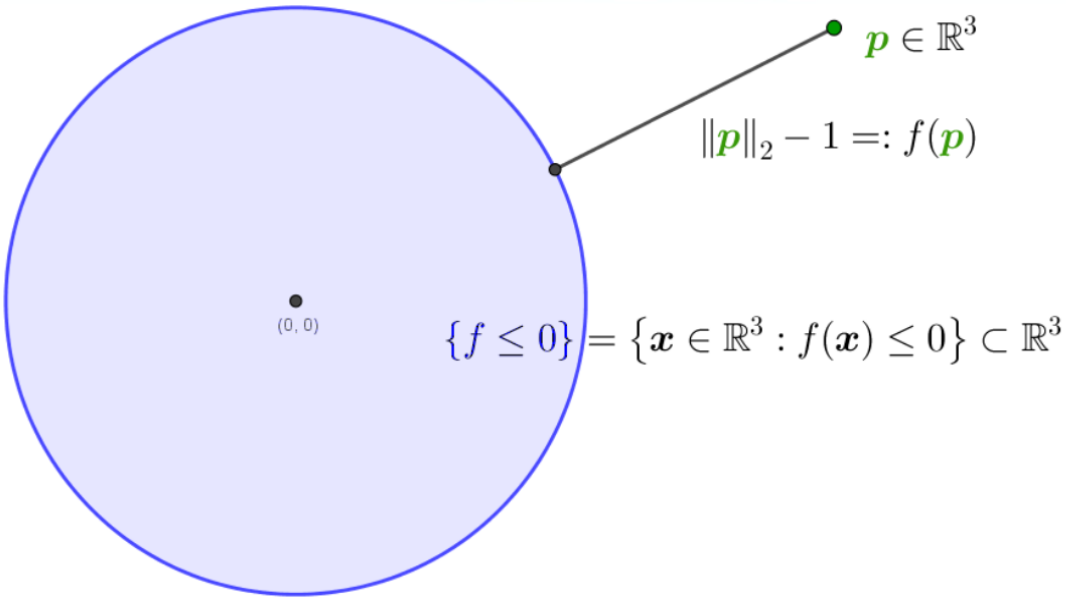
SIGNED DISTANCE FUNCTION AND FIELD

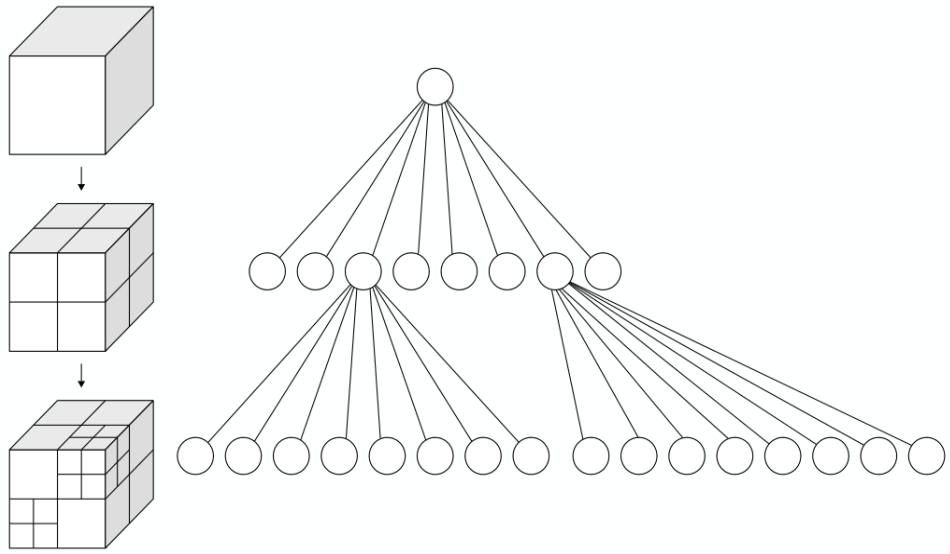


- f(p) is the distance from p to the surface;
- Negative if inside, positive if outside;
- Example:
  - Unit sphere: $f(p) = \|p\|_2 - 1.$

$$f(p) = \begin{cases} d(p, \partial\Omega), if\ p \notin \Omega \\ -d(p, \partial\Omega), if\ p \in \Omega \end{cases}$$

OCTREE

- Spatial data structure;
- Eight children;
- Much less memory footprint;
- Quick access to SDF values;
- High level of regularity;
- GPU friendly.



DISCRETIZING SDFs USING OCTREES
OCTREE CREATION

Steps

1. Calculate root node's bounding box;
2. Recursively create child nodes until:
    1. A depth limit has been reached, or
    2. The number of triangles inside the node's bounding box is below a predefined value, or
    3. Discretization error is negligible;

Subproblem 1:

Box ∩ *Triangle* ➔ *Separating Axis Theorem;*

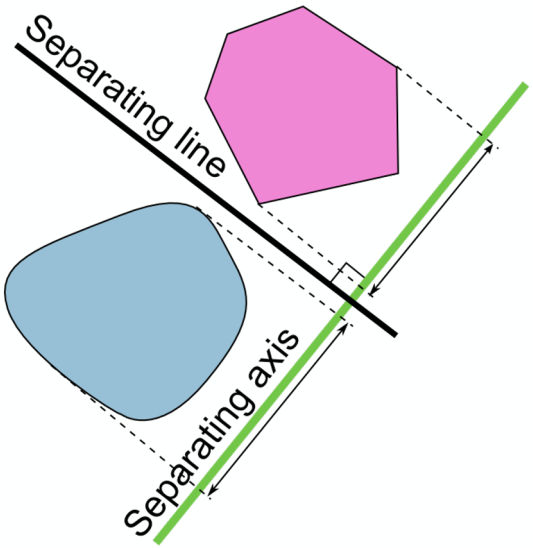
Subproblem 2:

SDF computing for corners of leaf nodes.

DISCRETIZING SDFs USING OCTREES
OCTREE CREATION: SEPARATION AXES THEOREM

- Intersection of convex shapes;
- Separating hyperplane;
- Project objects onto perpendicular axes;
- Do the intervals overlap?
- Find non-overlapping axis.
- If there is none, shapes intersect.
- For box and triangle, 13 tests.

"If two convex objects are not penetrating, there exists an axis for which the projection of the objects will not overlap."



DISCRETIZING SDFs USING OCTREES
OCTREE CREATION: SDF COMPUTING

Steps

1. For every leaf's corner:
    1. Calculate SDF values for all nearby triangles;
    2. Keep minimum;

DISCRETIZING SDFs USING OCTREES
OCTREE CREATION: SDF COMPUTING

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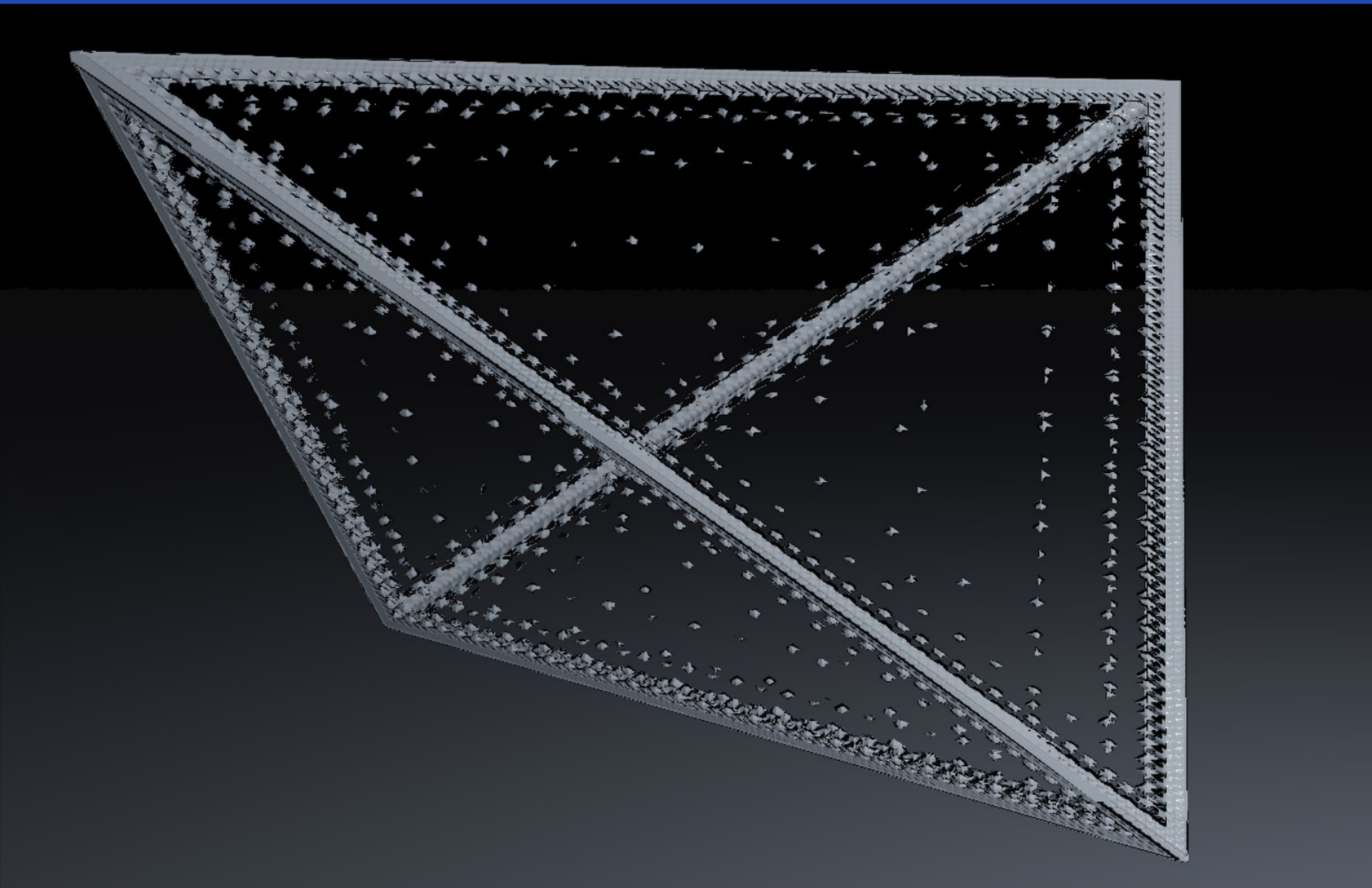
Does it work?

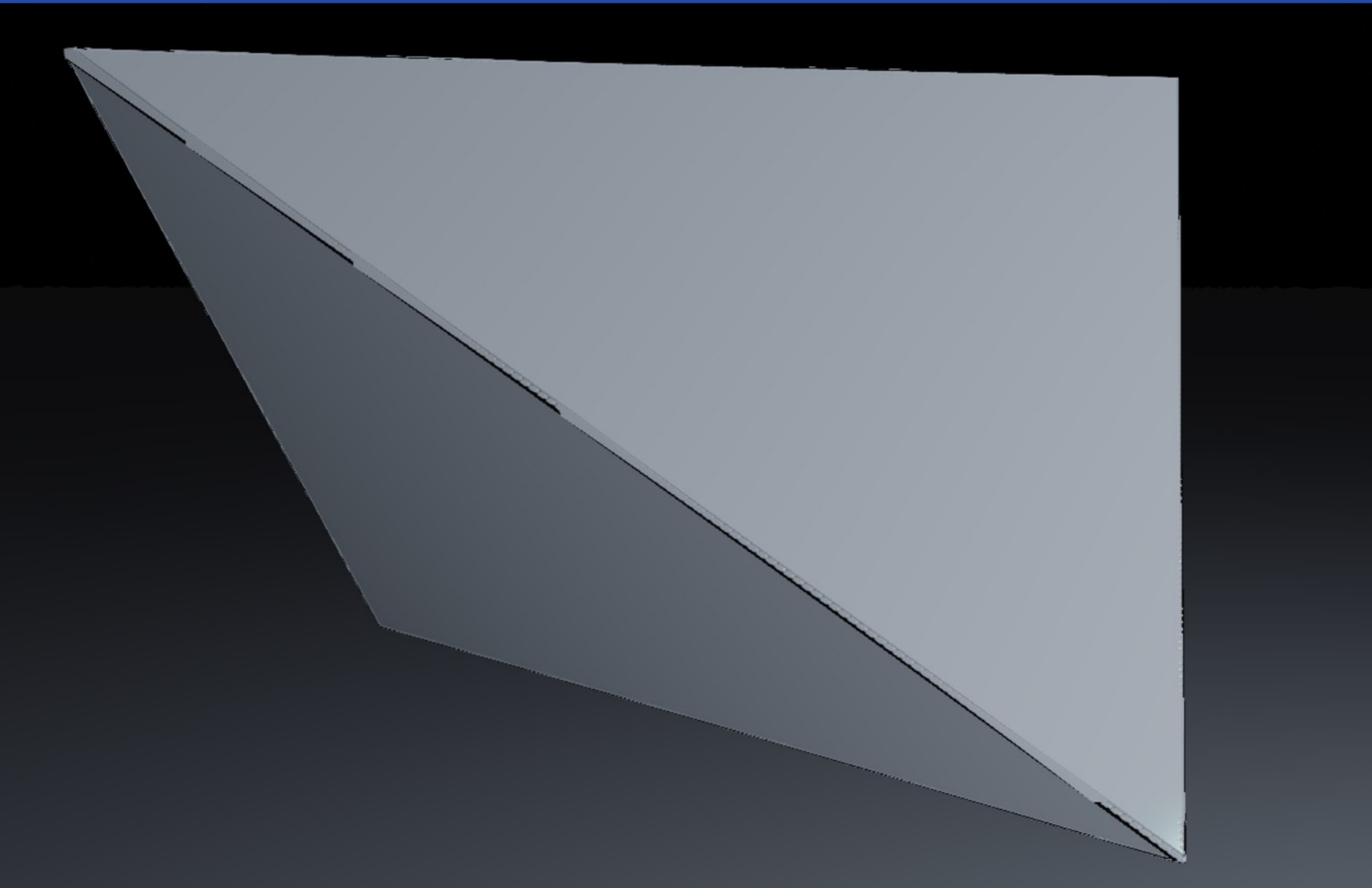
DISCRETIZING SDFs USING OCTREES

OCTREE CREATION: SDF COMPUTING



DISCRETIZING SDFs USING OCTREES

INSIDE/OUTSIDE PARTITION (PAINTING)



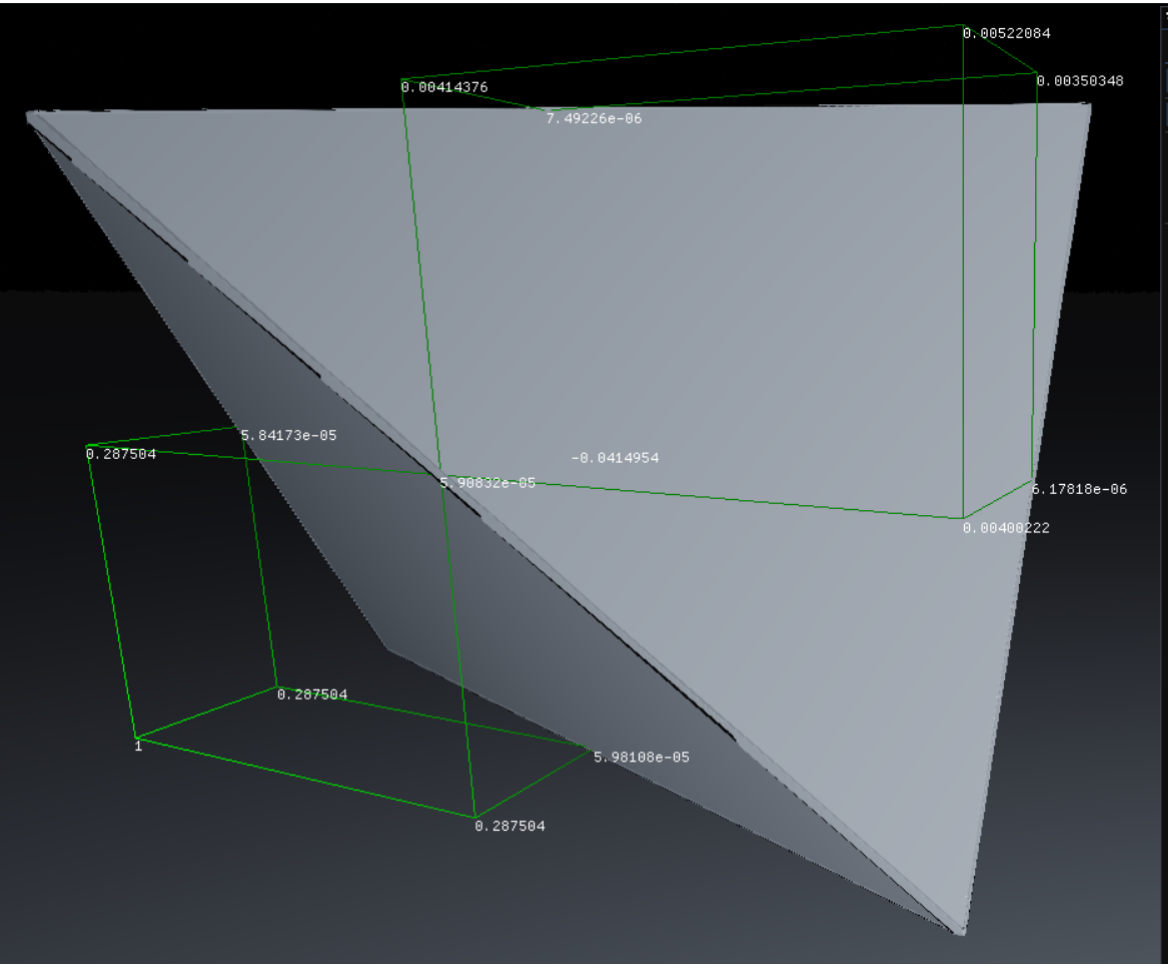
DISCRETIZING SDFs USING OCTREES
INSIDE/OUTSIDE PARTITION (PAINTING)

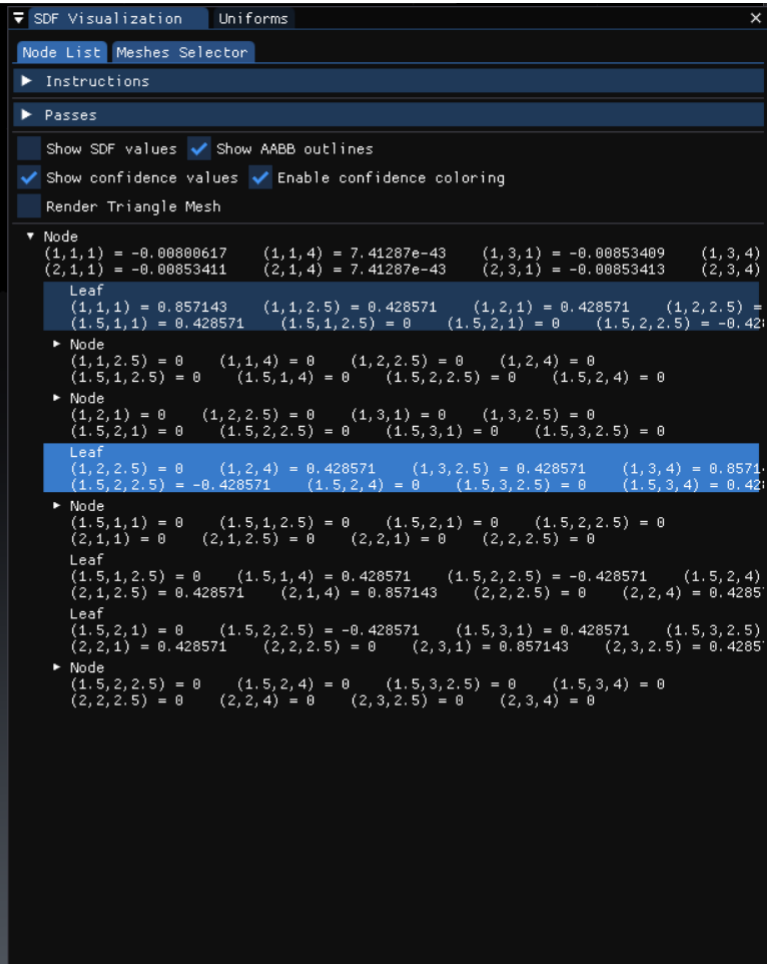
Confidence based graph

- The graph is composed by a set of all node's corners in the octree
- Edges are all edges from all leaf nodes and their box diagonals
- Each vertex in the new graph has a confidence $-1.0 \leq c \leq 1.0$

DISCRETIZING SDFs USING OCTREES

INSIDE/OUTSIDE PARTITION (PAINTING)





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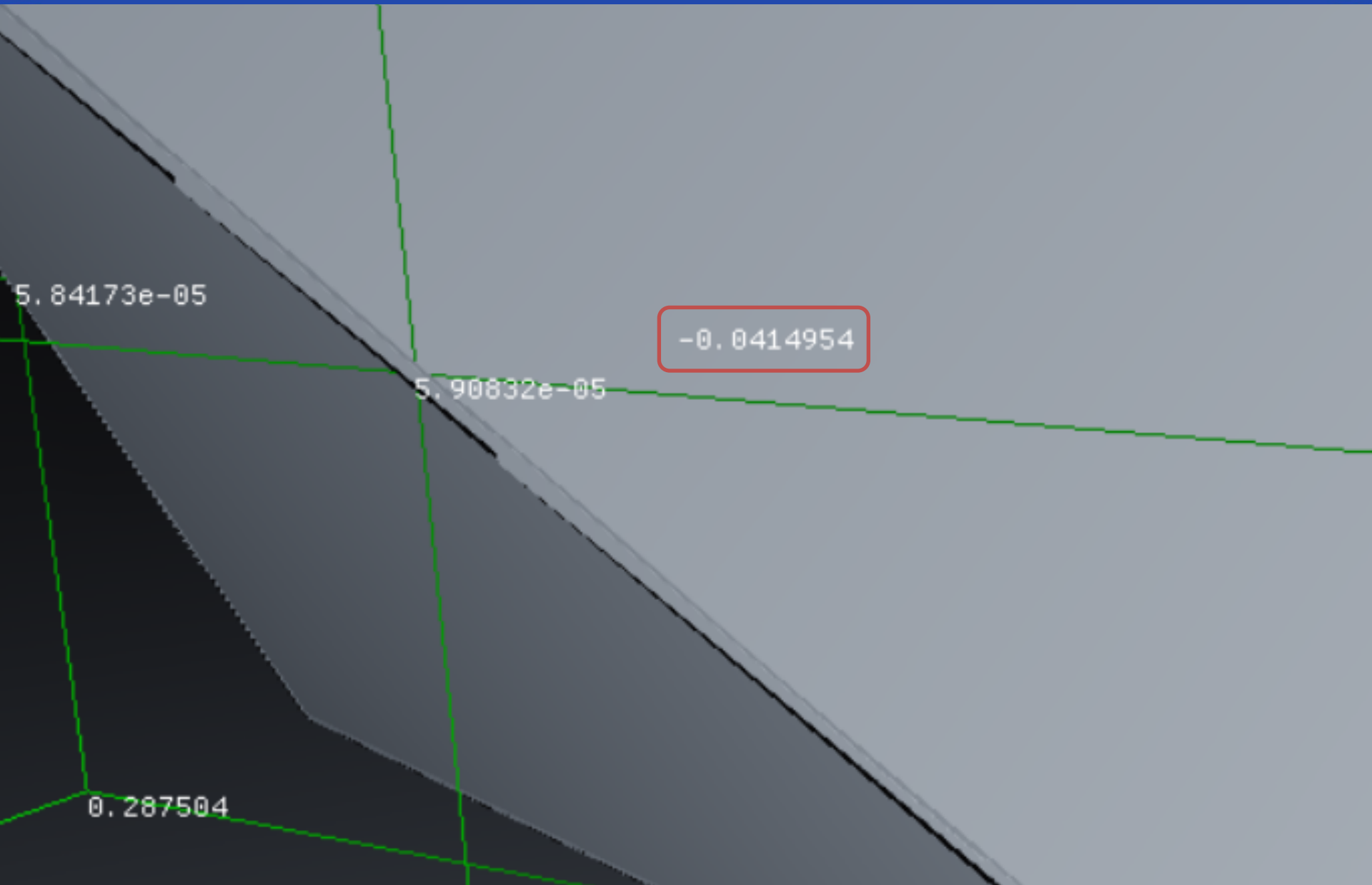

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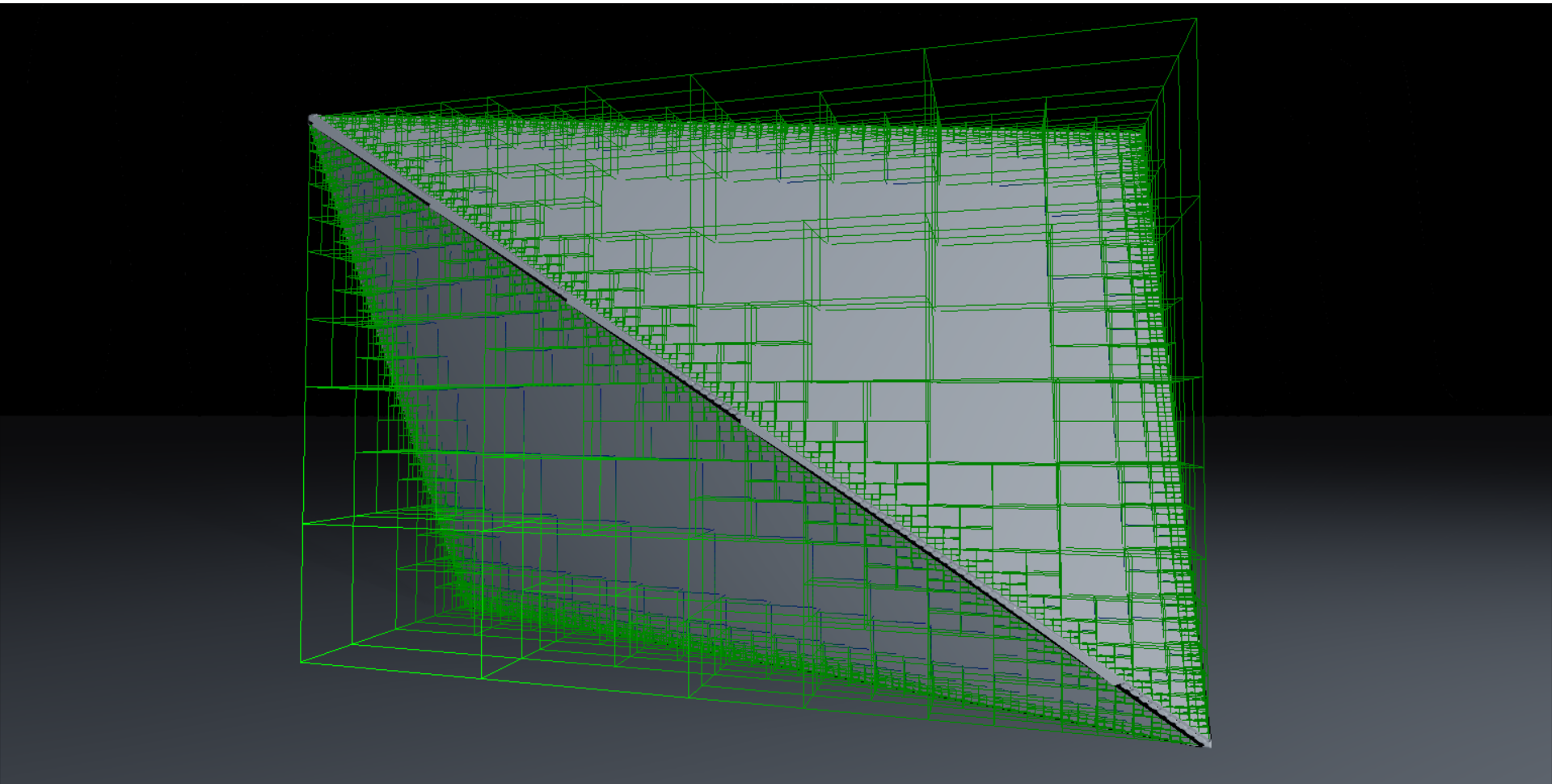
Confidence computing algorithm

- Starting node: utmost negative corner, c = 1.0
- Priority queue hosts unprocessed nodes (highest confidence first)
- Confidence of a node = weighted average of neighbors' confidence

1) Apply Lipschitz Continuity ➔ solves a set of nodes
2) Undecided nodes ➔ triangle intersection count

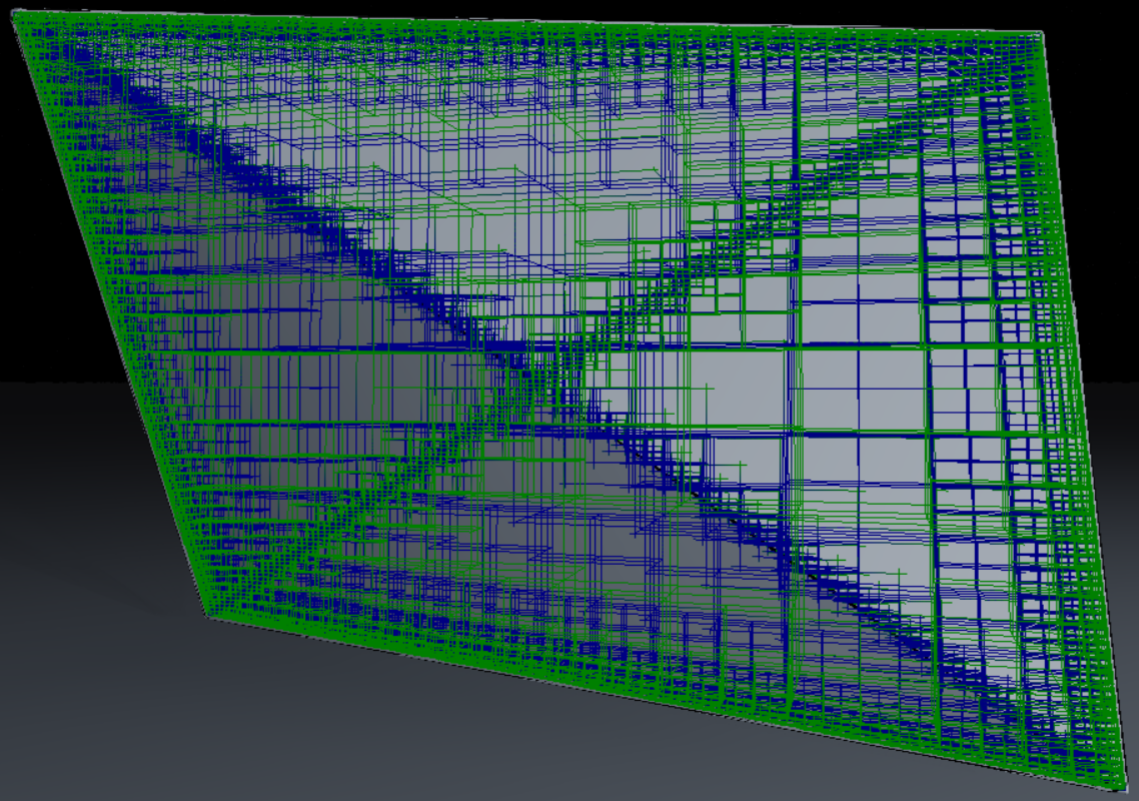
DISCRETIZING SDFs USING OCTREES
INSIDE/OUTSIDE PARTITION (PAINTING)

Outside



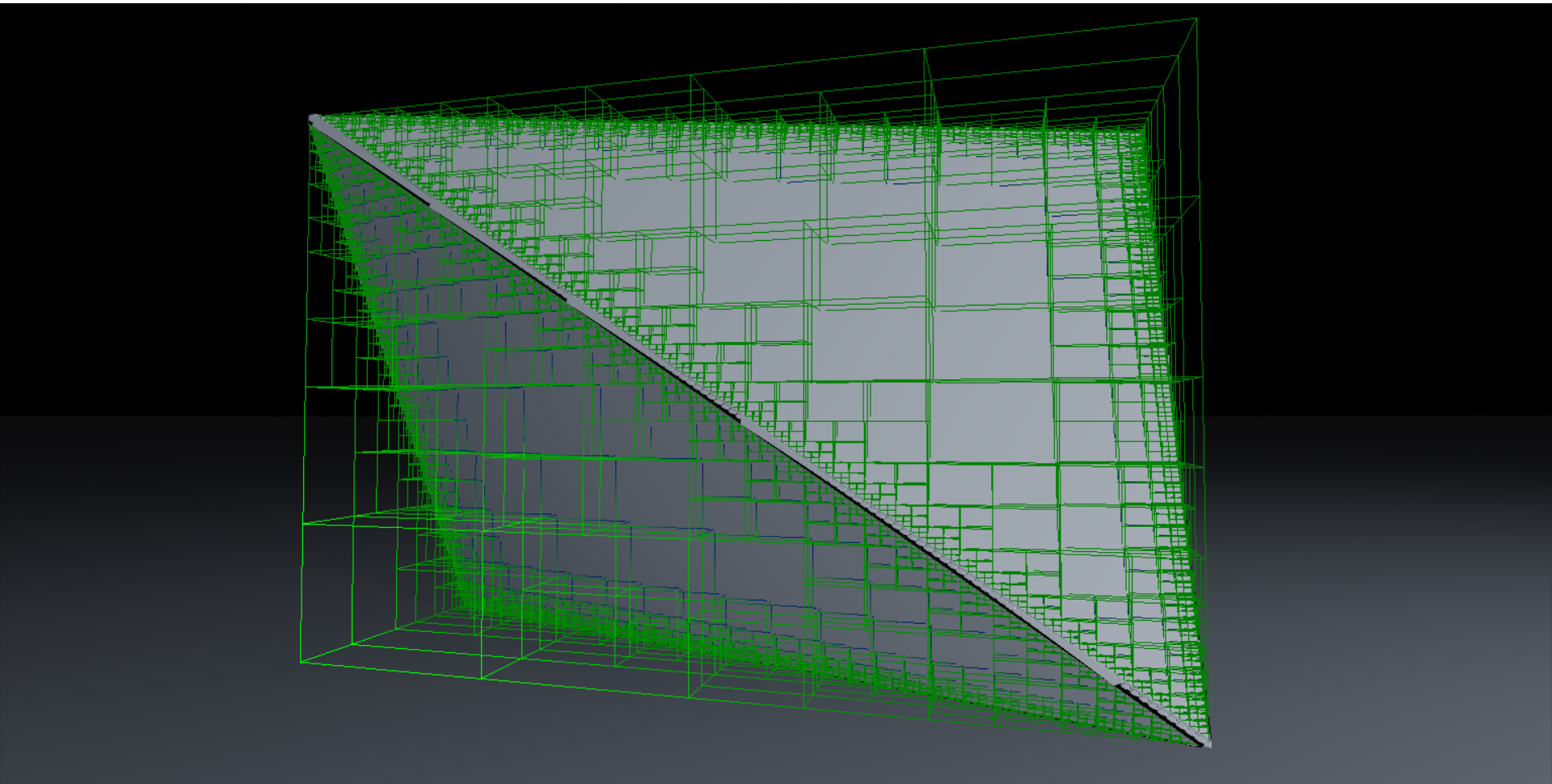
DISCRETIZING SDFs USING OCTREES
INSIDE/OUTSIDE PARTITION (PAINTING)

Inside



DISCRETIZING SDFs USING OCTREES
OPTIMIZATIONS

Number of nodes: 21.801



DISCRETIZING SDFs USING OCTREES
OPTIMIZATIONS

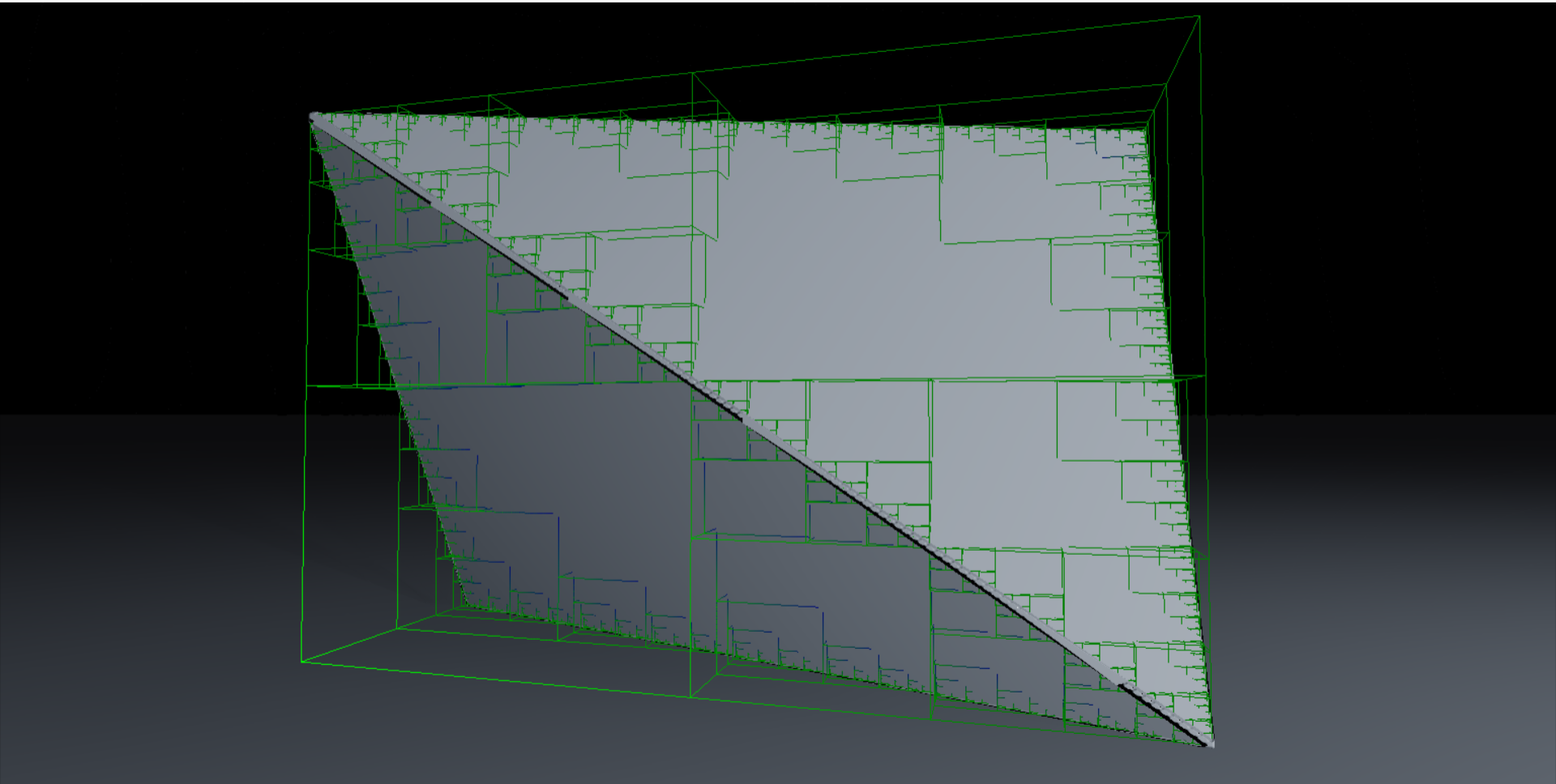
Adaptively Sampled Distance Fields (ADFs)

- Removes unnecessary child nodes

- Child nodes are removed if their sdf values can be approximated interpolating the parent's sdf values

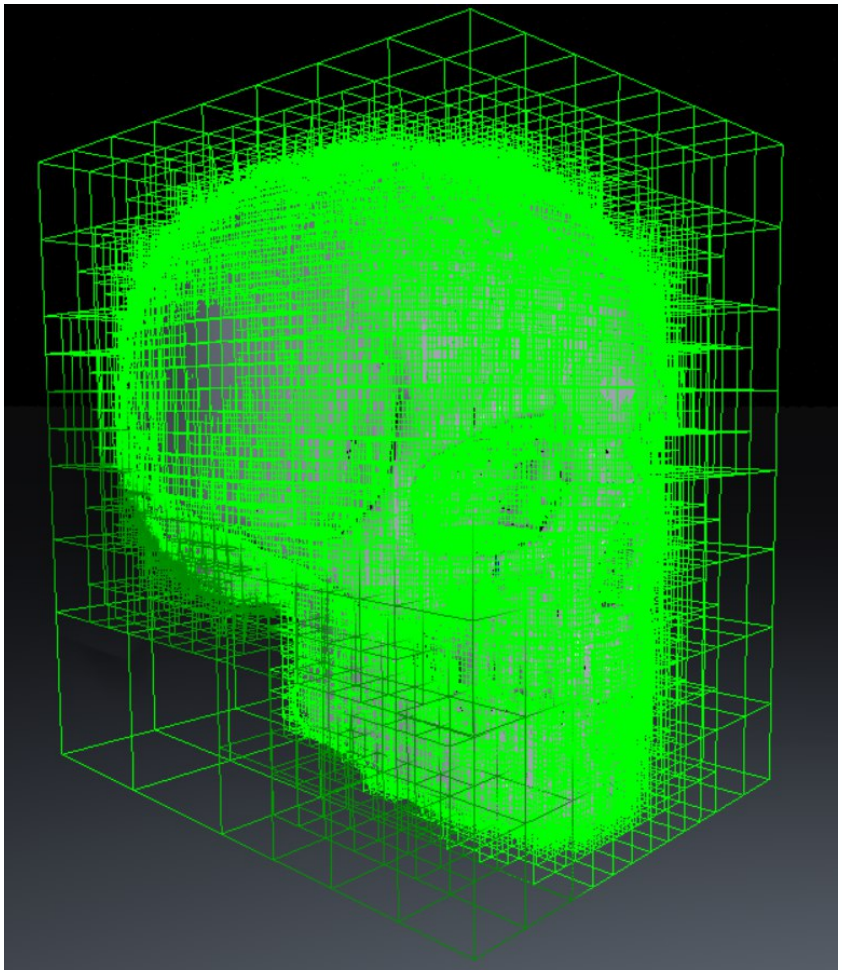
DISCRETIZING SDFs USING OCTREES
OPTIMIZATIONS

Number of nodes: 10.825 (-50%)



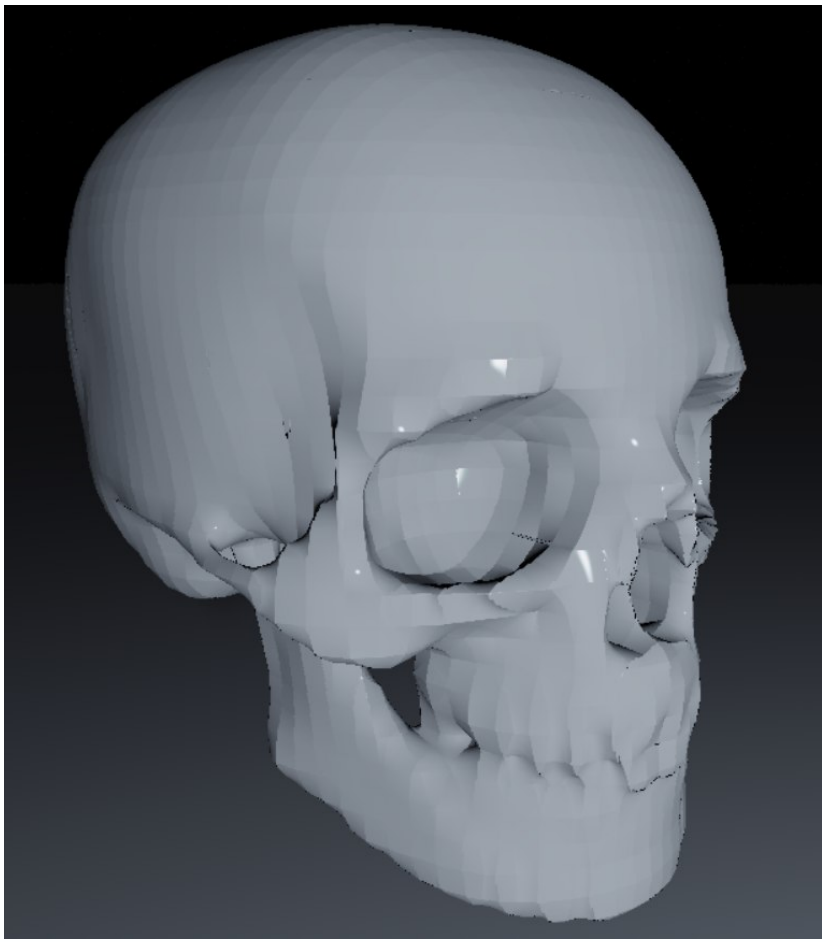
RESULTS

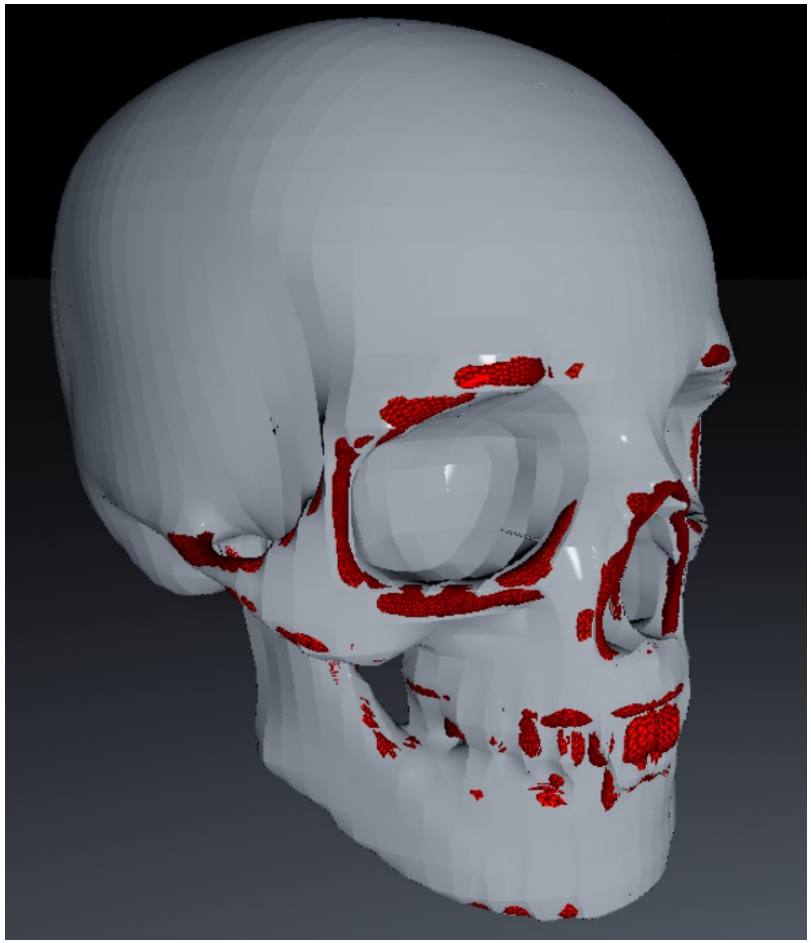
81.000 triangles, octree depth: 7



RESULTS
SDF vs TRIANGLE LIST

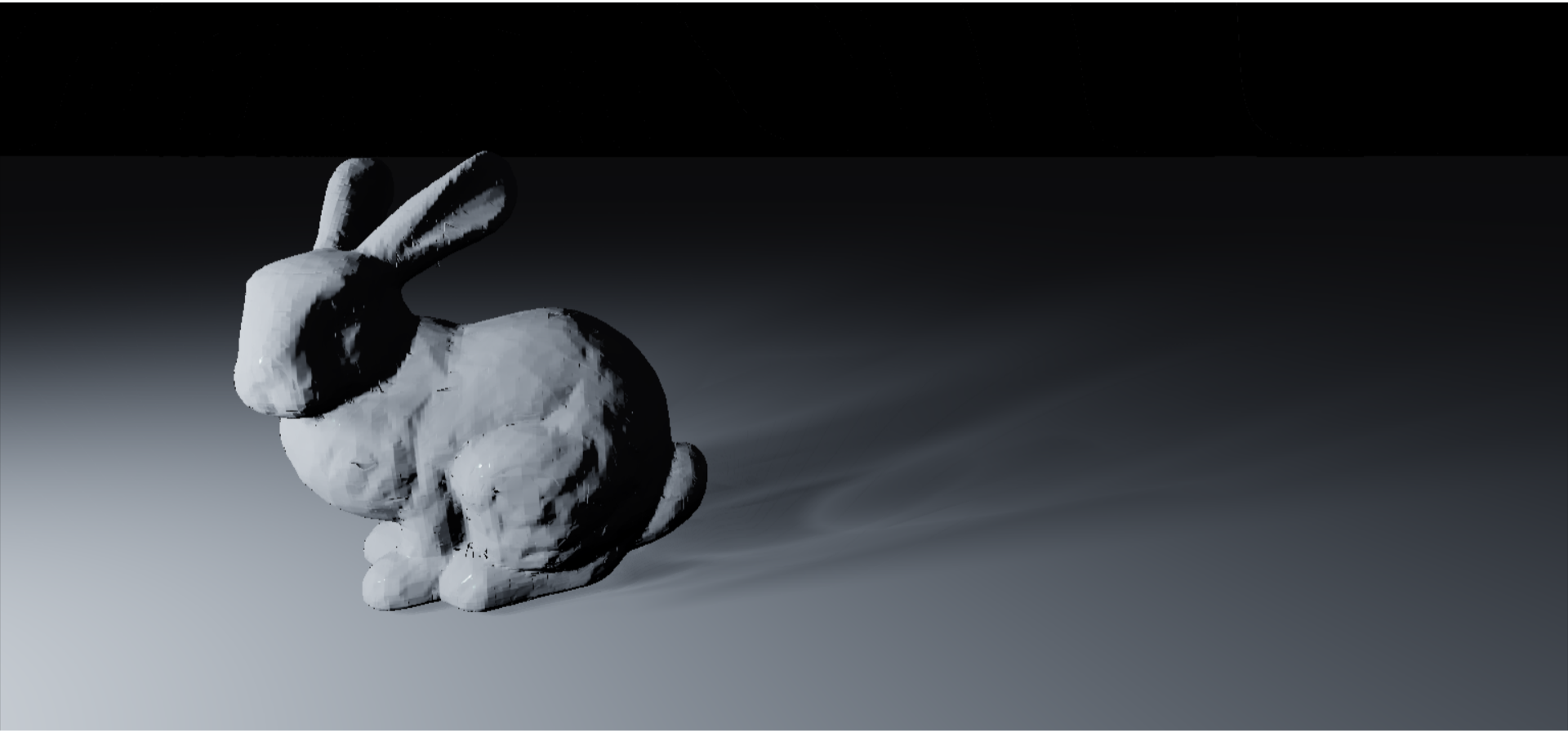
81.000 triangles, octree depth: 5





RESULTS
SOFT SHADOWS

5.002 triangles, octree depth: 7



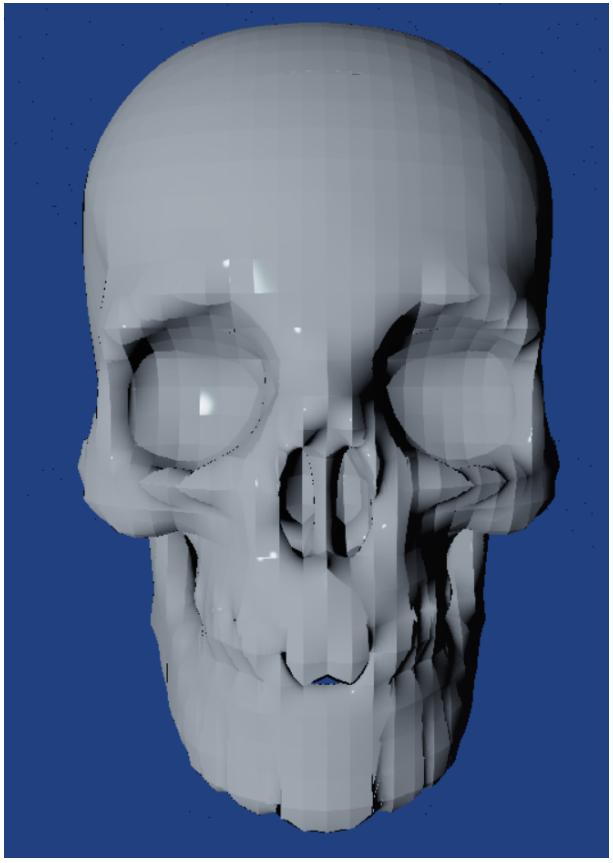
RESULTS
SOFT SHADOWS

12776 triangles, octree depth: 5

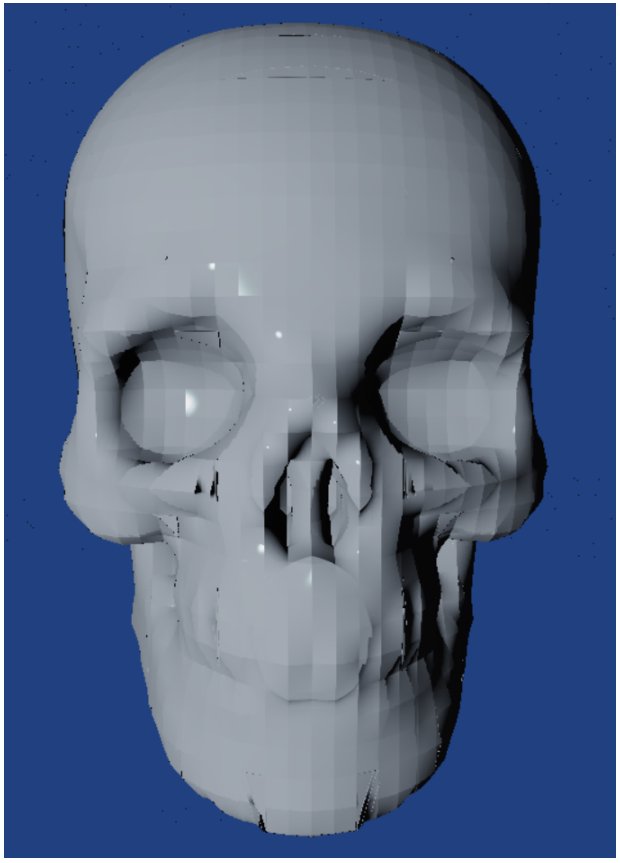
RESULTS
OFFSET OPERATION

5.002 triangles, octree depth: 5

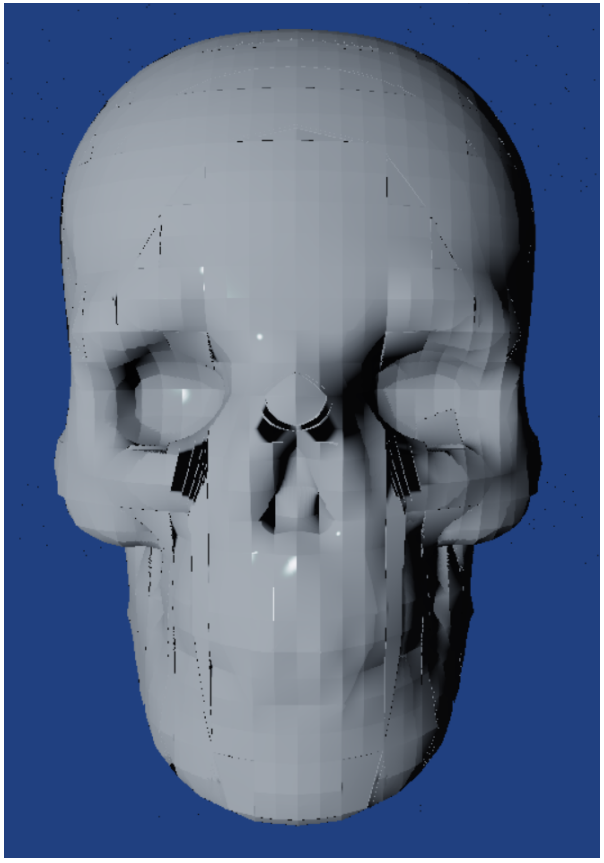
Original



Offset



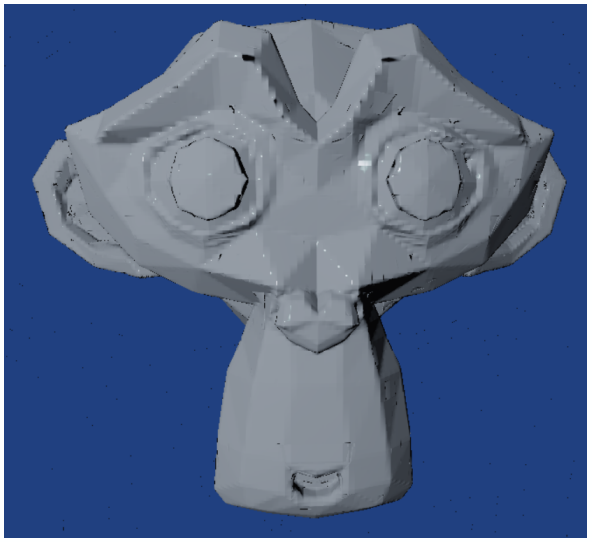
More Offset



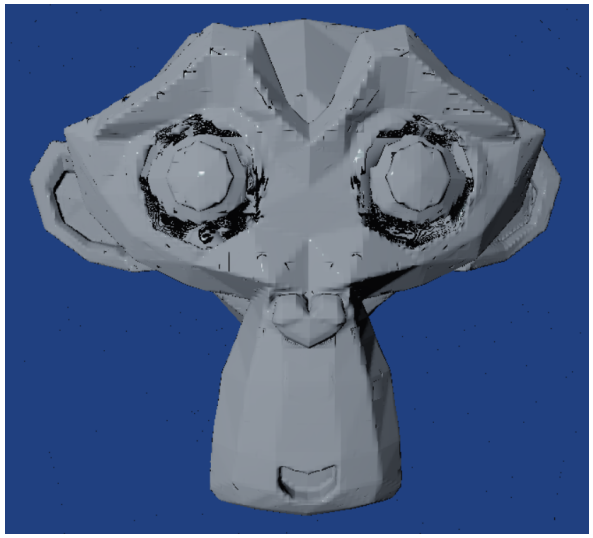
RESULTS
NEGATIVE OFFSET OPERATION

5.002 triangles, octree depth: 5

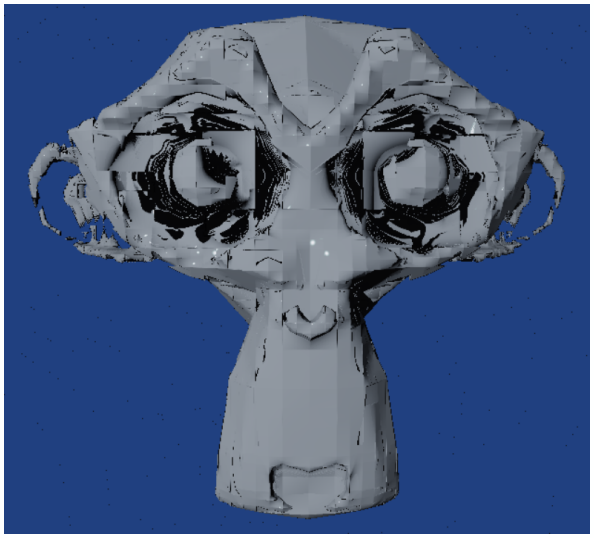
Original



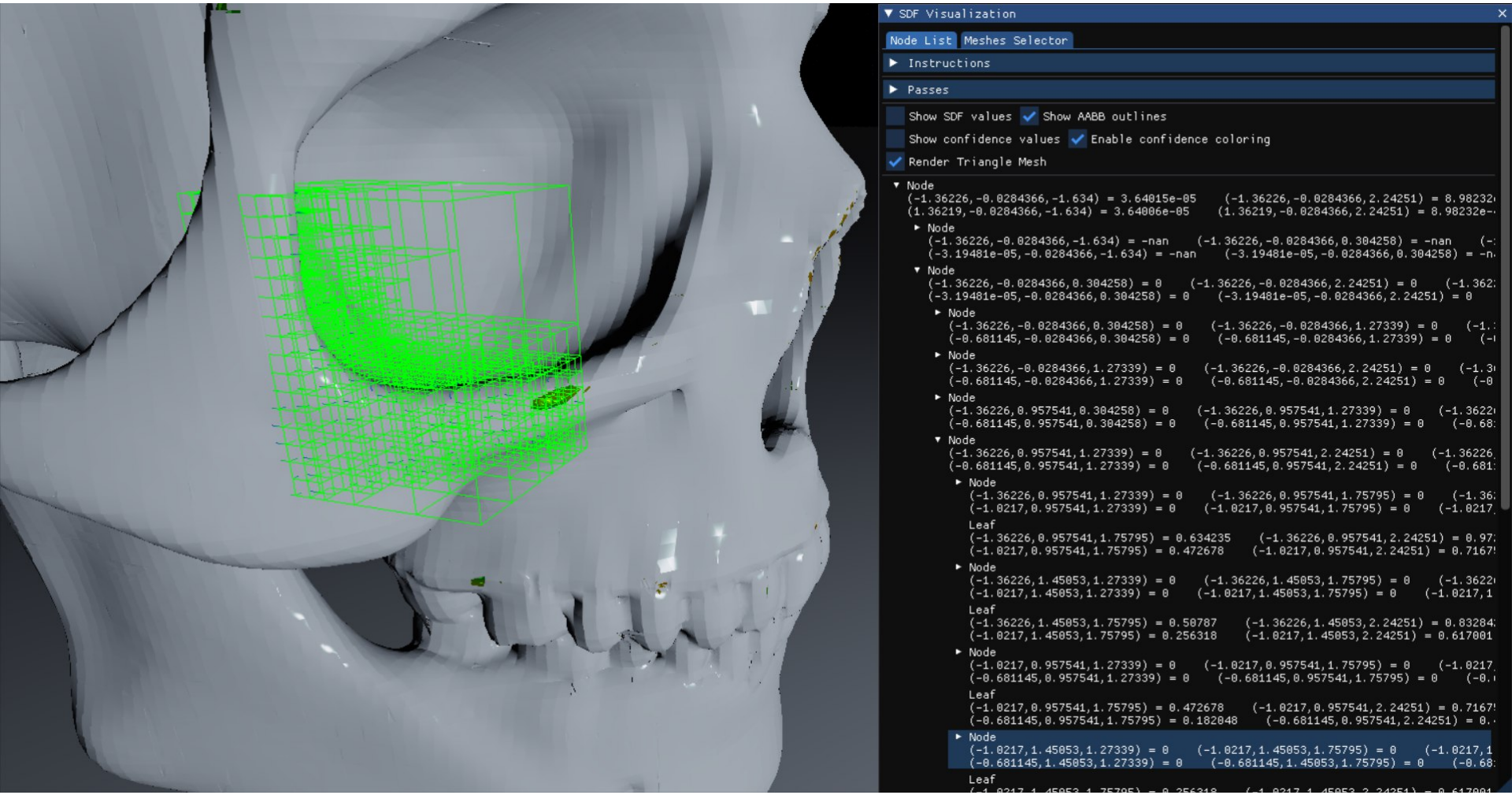
Offset



More Offset



DEBUGGING TOOL



FUTURE WORK

- Optimize generation to support **live updates;**
- Parallelize creation and painting of octree;
- Introduce more interpolation techniques for smoother results;
- Rediscretization with offset surfaces yield shape deformations.

THANK YOU FOR YOUR ATTENTION!

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