

# Octree-based Approach for Real-time Visualization of Surfaces Defined by Signed Distance Fields

Author: Pedro Figueirêdo

Supervisors: Bálint Csaba, Dr. Zsók Viktória

Eötvös Loránd University,  
Faculty of Informatics

Thesis Defense

Budapest,  
January 03, 2020

EFOP-3.6.3-VEKOP-16-2017-00001



European Union  
European Social  
Fund



INVESTING IN YOUR FUTURE

# MOTIVATION

- Real-time rendering engine
- Implicit representations of complex shapes
- **Render engine is inefficient in rendering triangle lists**



Rendering of mesh containing 871,414 triangles

# TABLE OF CONTENTS

## 1. Background

- Signed Distance Function and Field
- Octree

## 2. Algorithms

- Octree Construction
- SDF Computation
- Octree Optimization

## 3. Results

- SDF vs Triangle List
- Offset Operation
- Soft Shadows

# 1 BACKGROUND

**SZÉCHENYI** 



HUNGARIAN  
GOVERNMENT

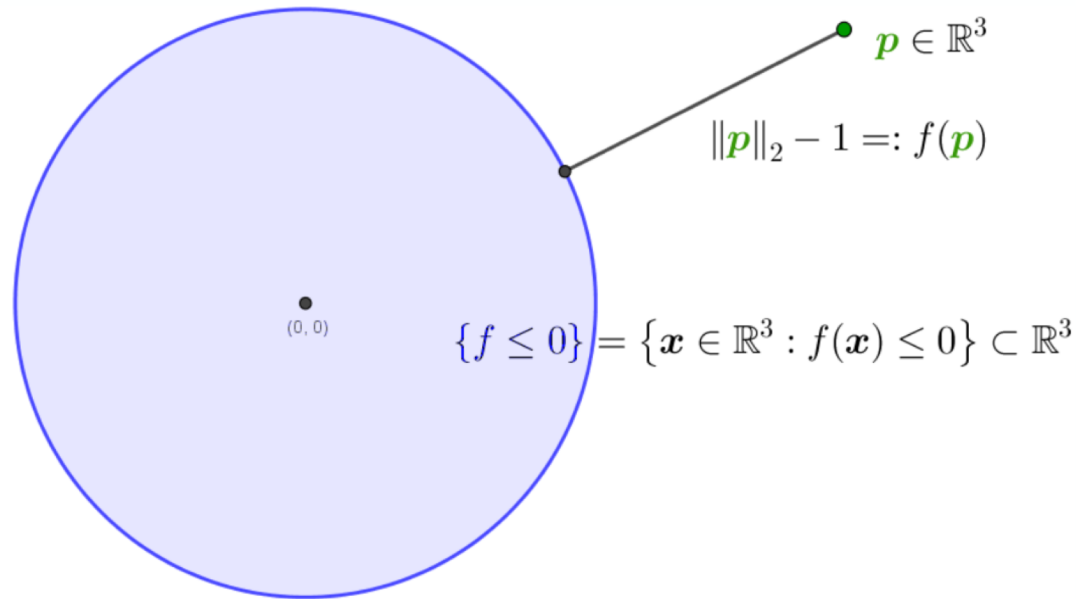
European Union  
European Social  
Fund



**INVESTING IN YOUR FUTURE**



# SIGNED DISTANCE FUNCTION

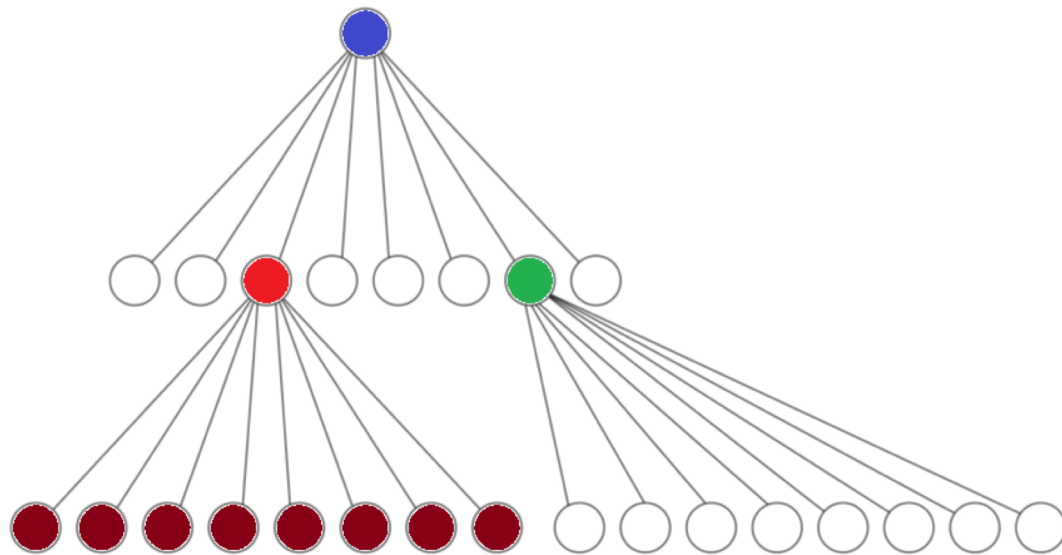
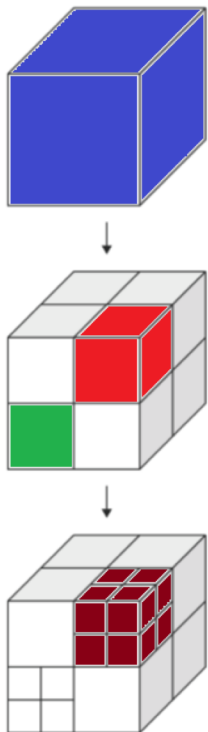


- $f(p)$  is the distance from  $p$  to the surface
- Negative if inside, positive if outside
- Example:
  - Unit sphere:  $f(p) = \|p\|_2 - 1$

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

# OCTREE

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



# 2 ALGORITHMS

**SZÉCHENYI** 



HUNGARIAN  
GOVERNMENT

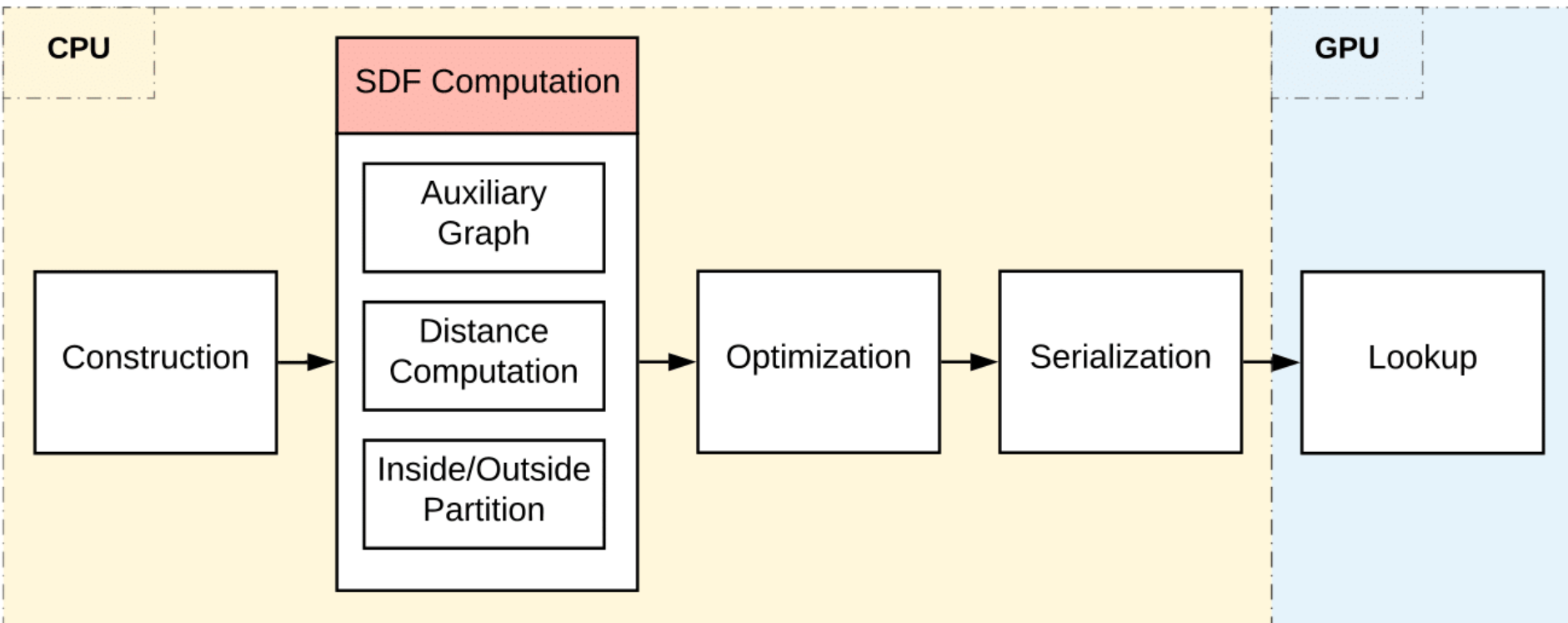
European Union  
European Social  
Fund



INVESTING IN YOUR FUTURE

# ALGORITHMS

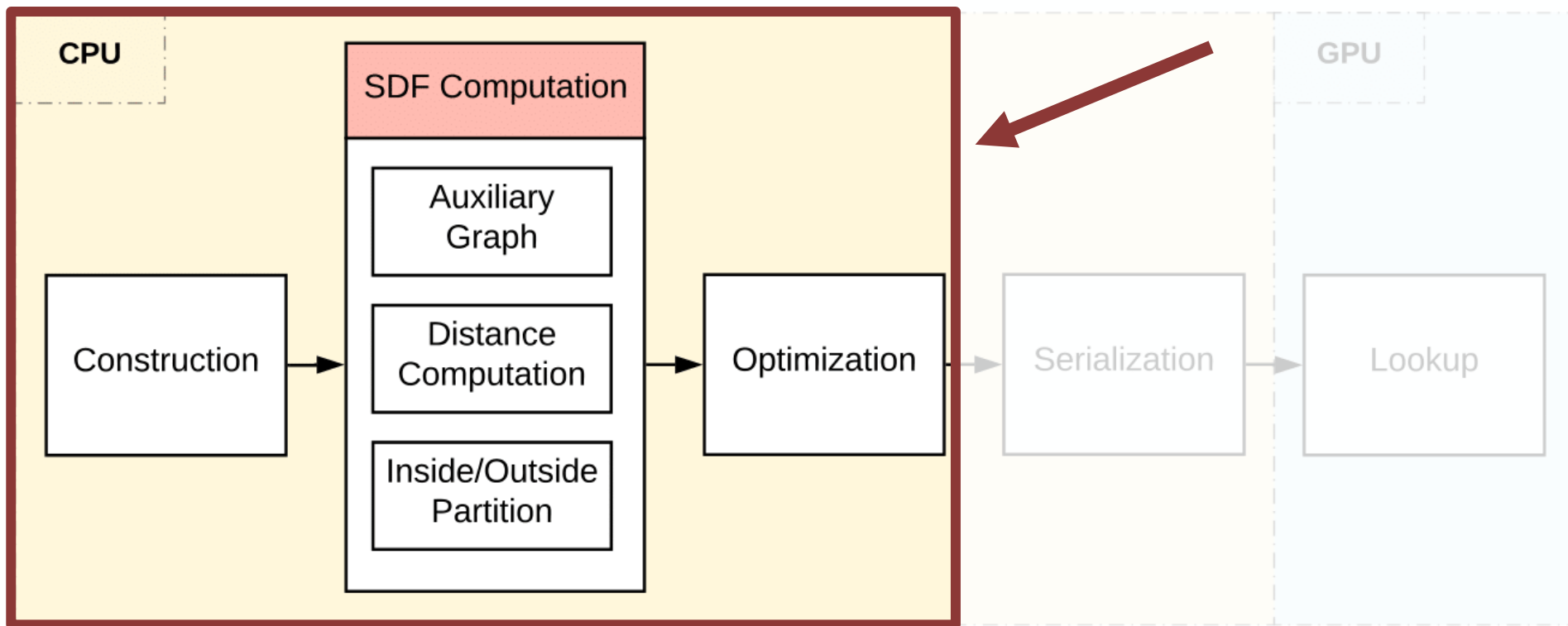
## WORKFLOW – SDF FROM TRIANGLE MESH



Workflow of octree algorithms following the natural order of execution

# ALGORITHMS

## WORKFLOW – SDF FROM TRIANGLE MESH



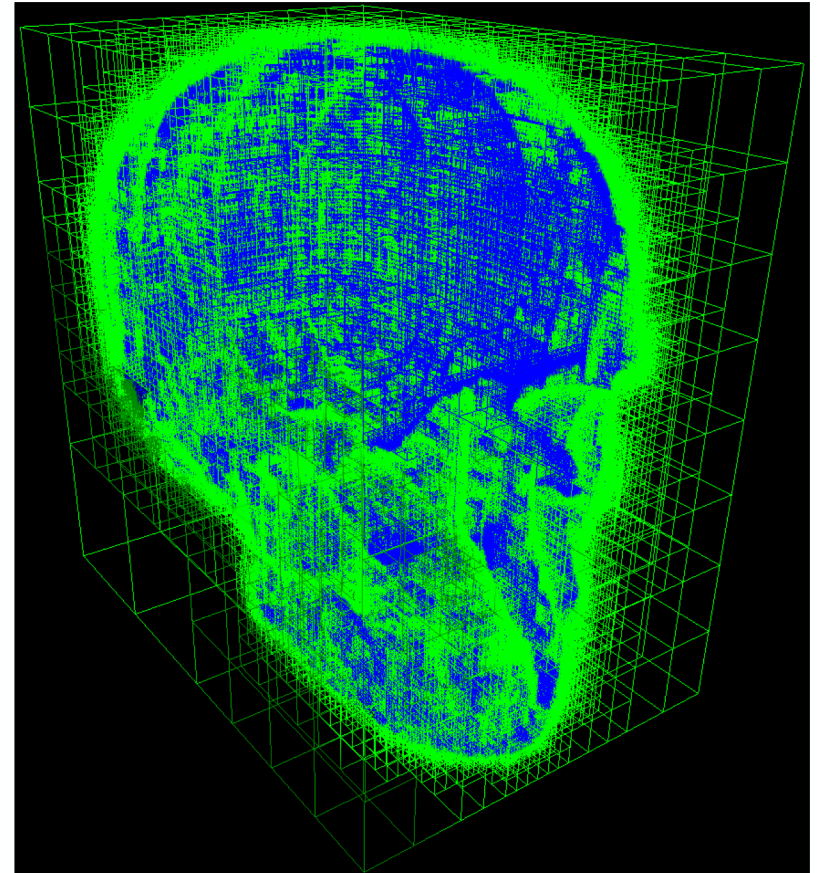
Workflow of octree algorithms following the natural order of execution

# ALGORITHMS

## OCTREE CONSTRUCTION

### Steps

1. Calculate root node's bounding box
2. Recursively create child nodes until:
  1. A depth limit has been reached
  2. The number of triangles is less than two
  3. Discretization error is negligible



# ALGORITHMS

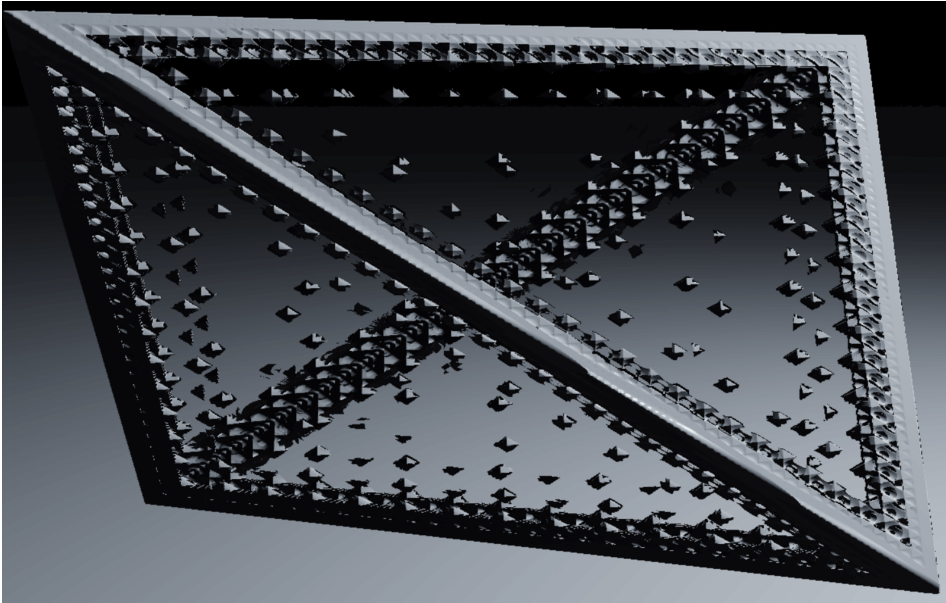
## SDF COMPUTING

### Steps

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

# ALGORITHMS

## SDF COMPUTING



**Without** Inside/Outside Partition

**With** Inside/Outside Partition





# ALGORITHMS

## SDF COMPUTING: INSIDE/OUTSIDE PARTITION

### Auxiliary 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**  $-1.0 \leq c \leq 1.0$

# ALGORITHMS

## SDF COMPUTING: INSIDE/OUTSIDE PARTITION

### Auxiliary 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  $-1.0 \leq c \leq 1.0$

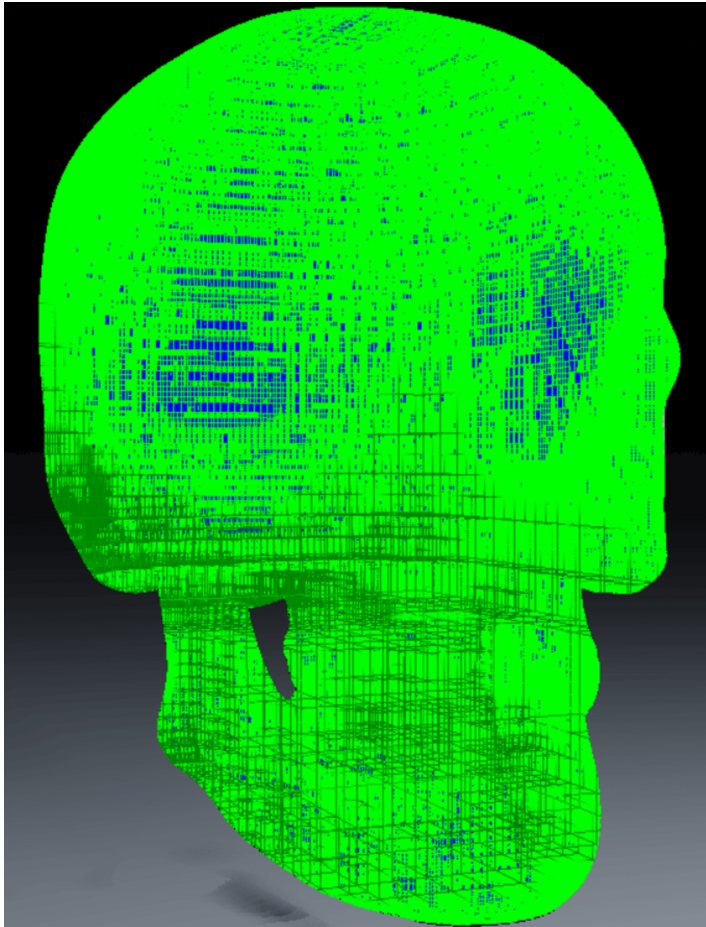
### Confidence computing algorithm

- 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

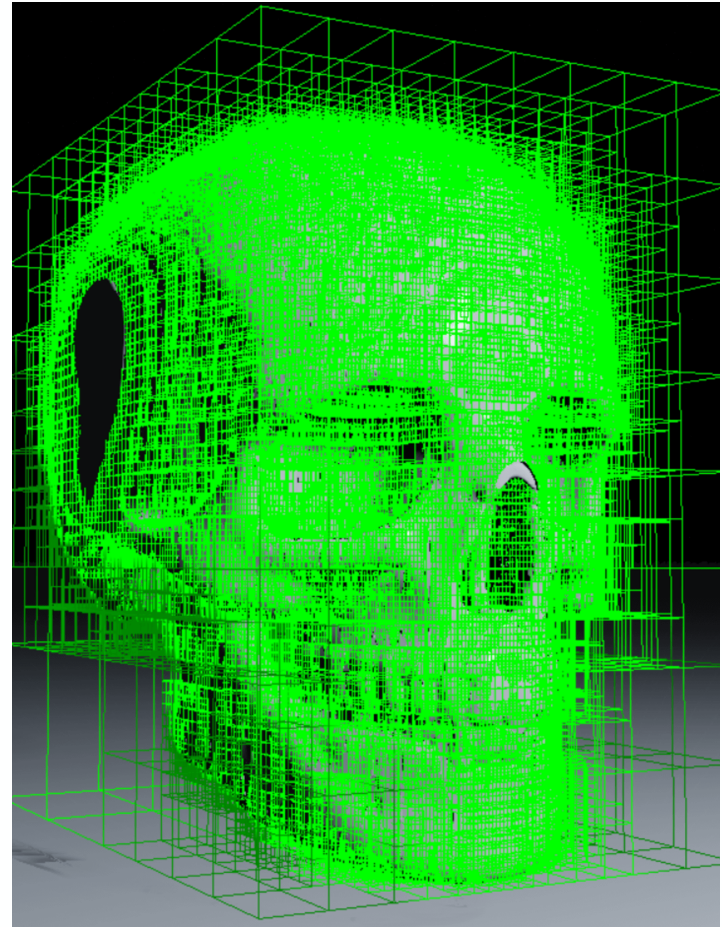
# ALGORITHMS

## SDF COMPUTING: INSIDE/OUTSIDE PARTITION

Inside



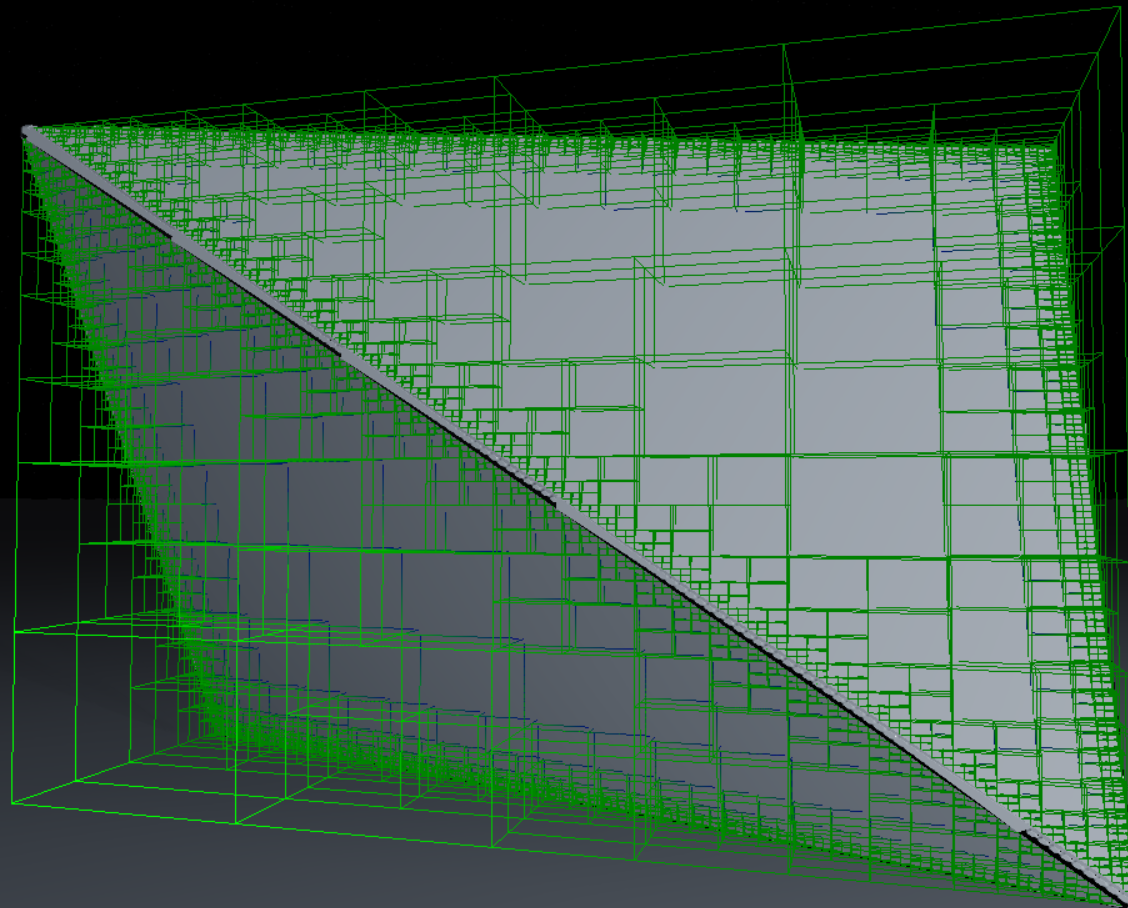
Outside



# ALGORITHMS

## OCTREE OPTIMIZATION

Number of nodes: 21.801

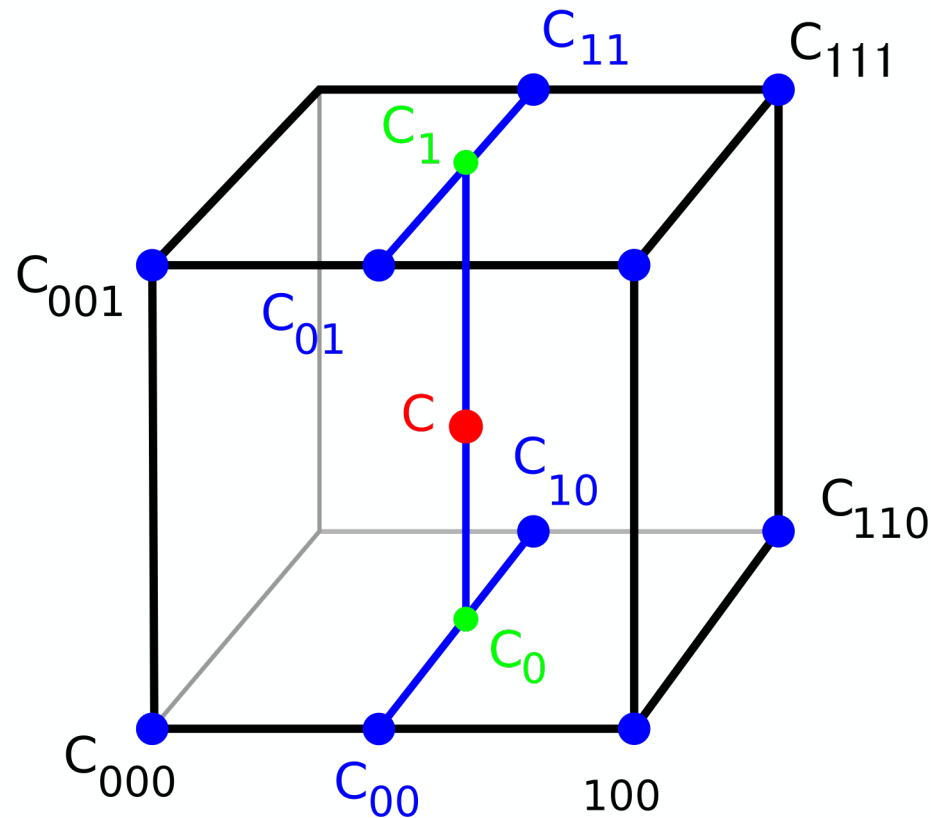


# ALGORITHMS

## OCTREE OPTIMIZATION

### Adaptively Sampled Distance Fields (ADFs)

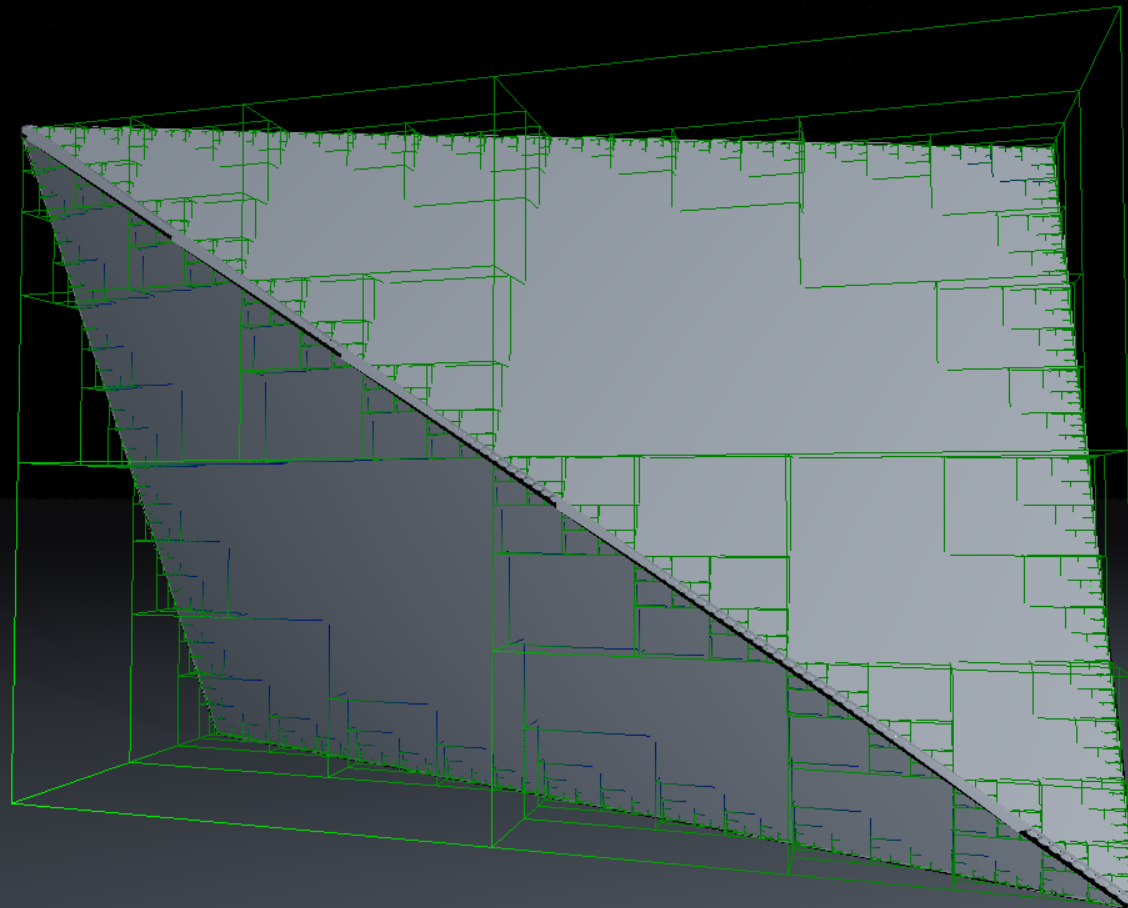
- Removes unnecessary child nodes
- Child nodes are removed if **trilinear interpolation** error is small



# ALGORITHMS

## OCTREE OPTIMIZATION

Number of nodes: 10.825 (-50%)



# 3 RESULTS

**SZÉCHENYI** 



HUNGARIAN  
GOVERNMENT

European Union  
European Social  
Fund



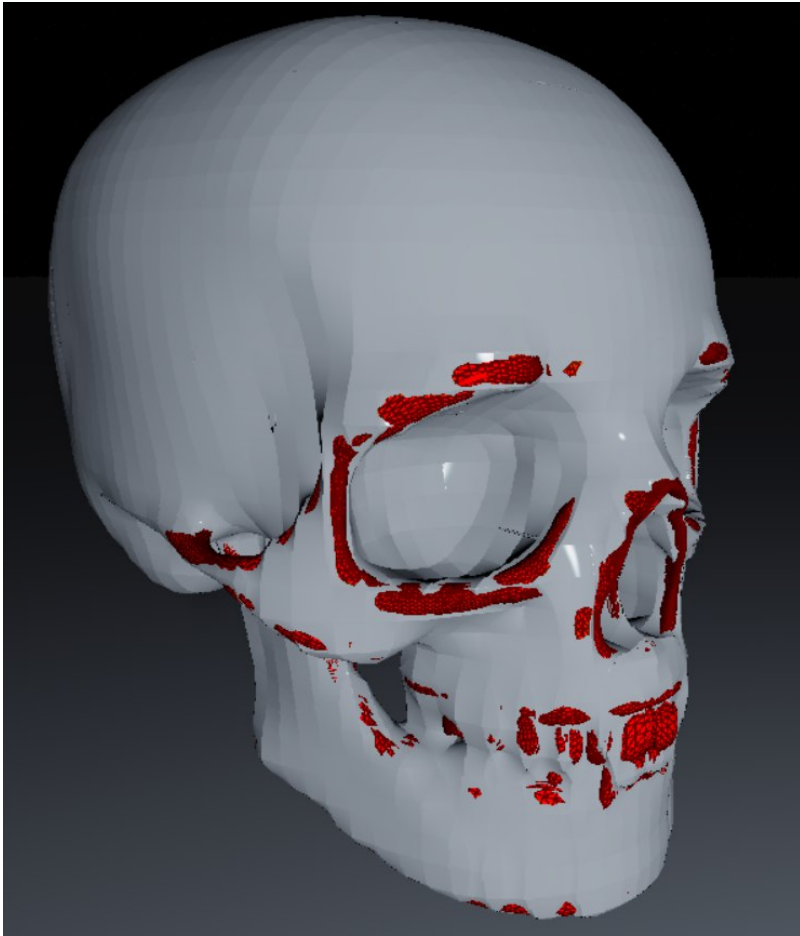
**INVESTING IN YOUR FUTURE**

# RESULTS

## SDF vs TRIANGLE LIST

81.000 triangles

octree depth: 5



octree depth: 7



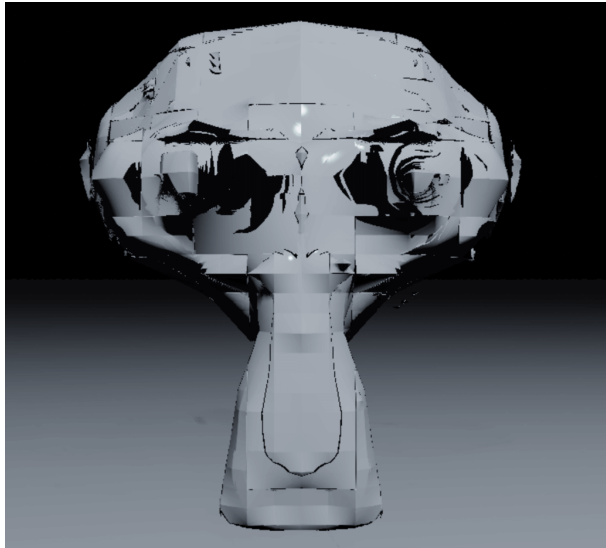


# RESULTS

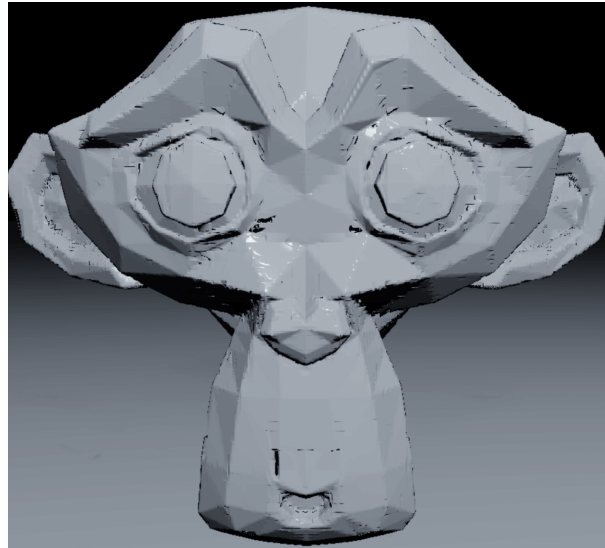
## OFFSET OPERATION

968 triangles, octree depth: 7

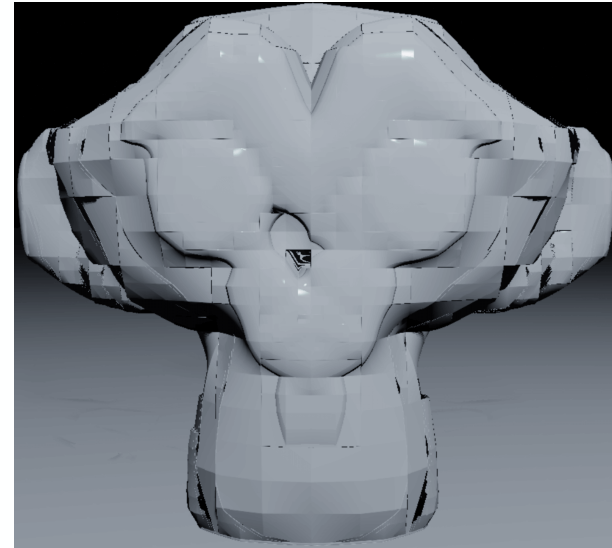
Negative Offset



Original



Positive Offset



# RESULTS

## SOFT SHADOWS

81.000 triangles, octree depth: 7



# RESULTS

## SOFT SHADOWS

871,414 triangles, octree depth: 7



Will be submitted to **CESCG 2020** as a short paper

## SUMMARY

- Octree construction from triangle mesh
- Novel solution for SDF computing and inside / outside partition
- Implicit representation allows offset and soft shadows. Other operations such as dilatation/erosion, and set-theoretic operations can be executed efficiently.

## FUTURE WORK

- More robust inside/outside partition and mesh correction
- Implement everything on the GPU
- Higher-order interpolations

# THANK YOU FOR YOUR ATTENTION!



European Union  
European Social  
Fund



INVESTING IN YOUR FUTURE

# EXTRA RESULTS

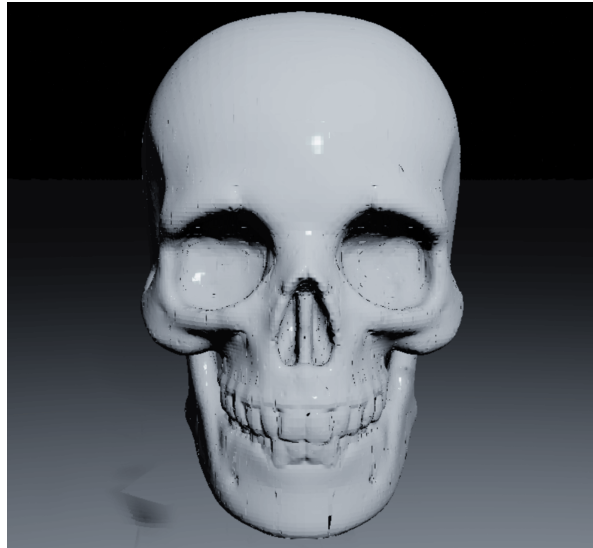
## DILATATION / EROSION OPERATIONS

81.000 triangles, octree depth: 7,  $d = 0.5$

Erosion



Original



Dilatation



# EXTRA RESULTS

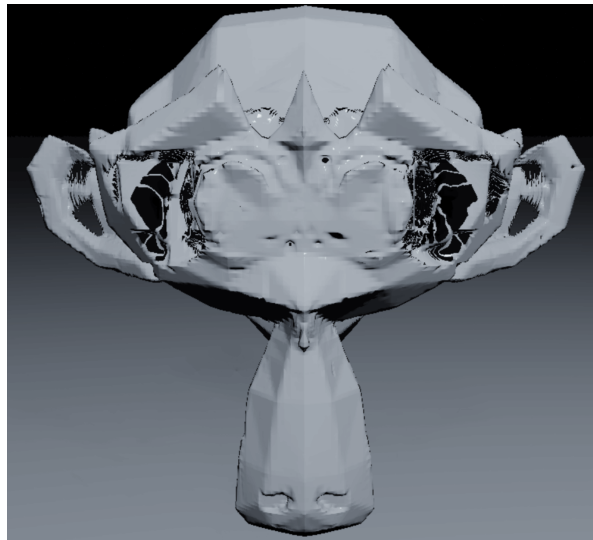
## SET-THEORETIC OPERATIONS

968 triangles, octree depth: 7

Union



Intersection



Difference

