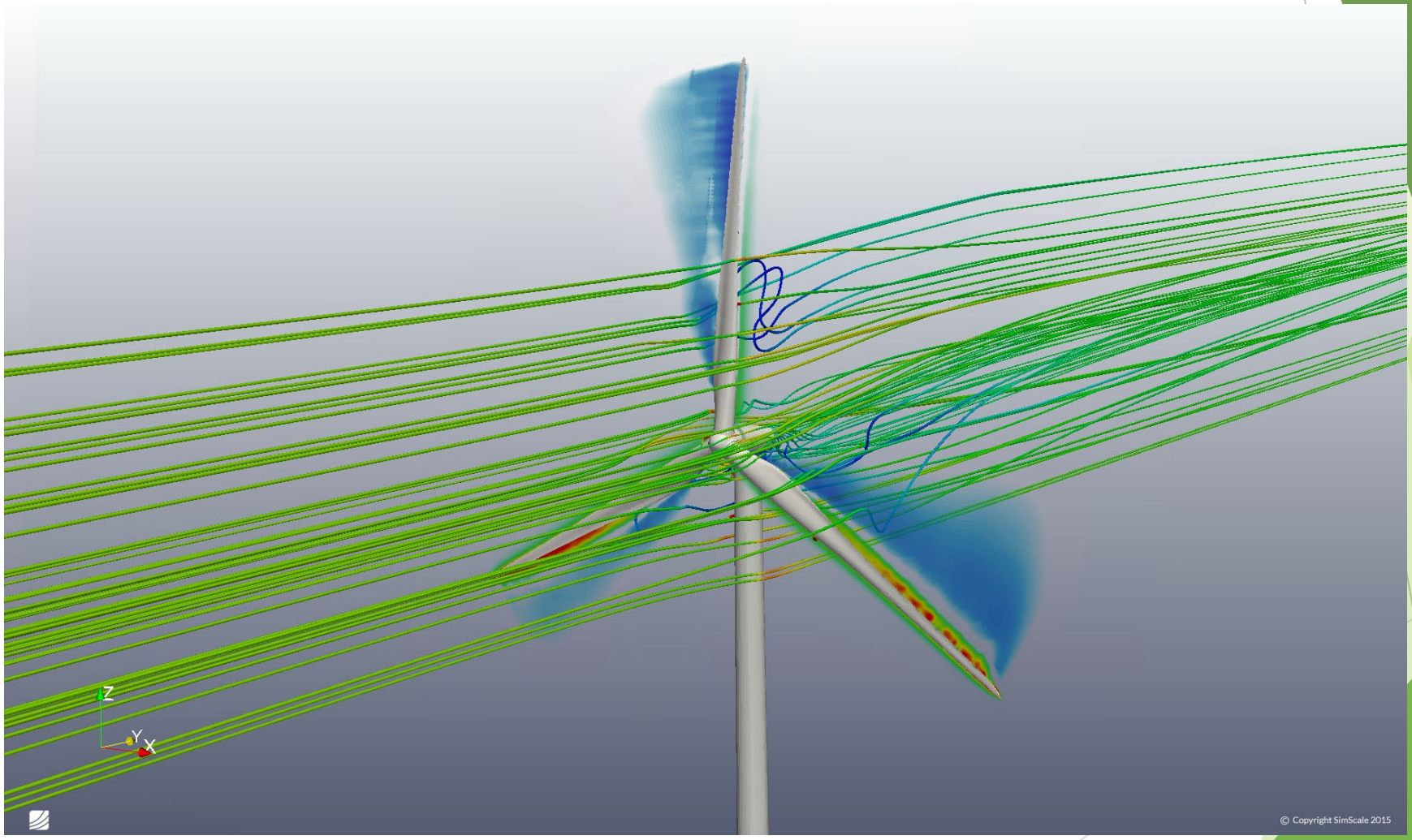
Visualizing massive CFD outputs in game engines using level of detail and dynamic loading

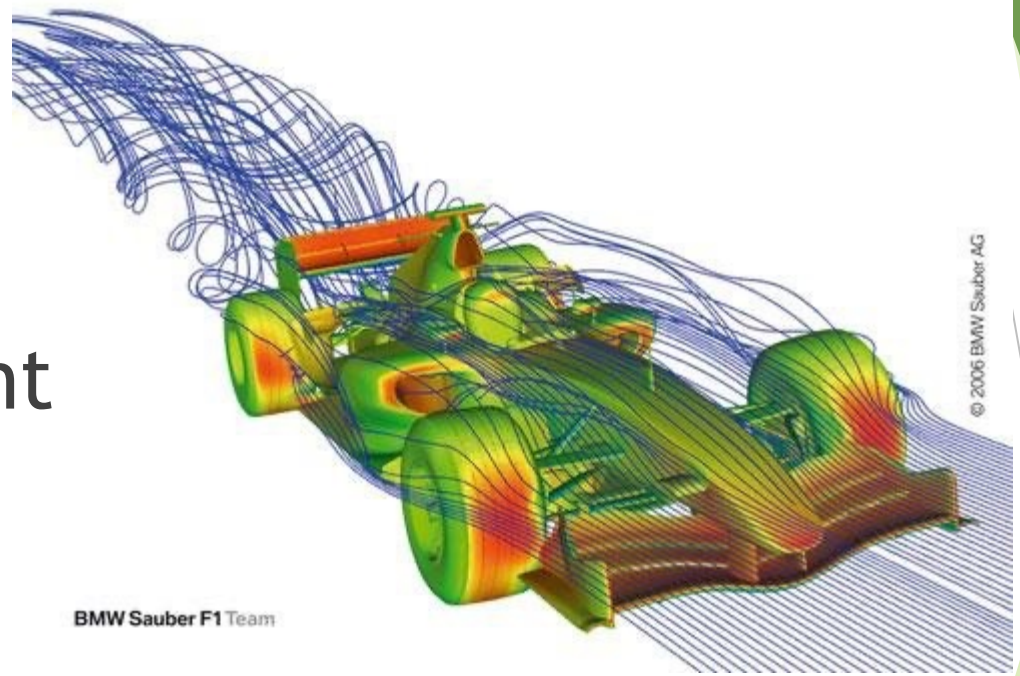
What is a CFD?



https://spectrum.ieee.org

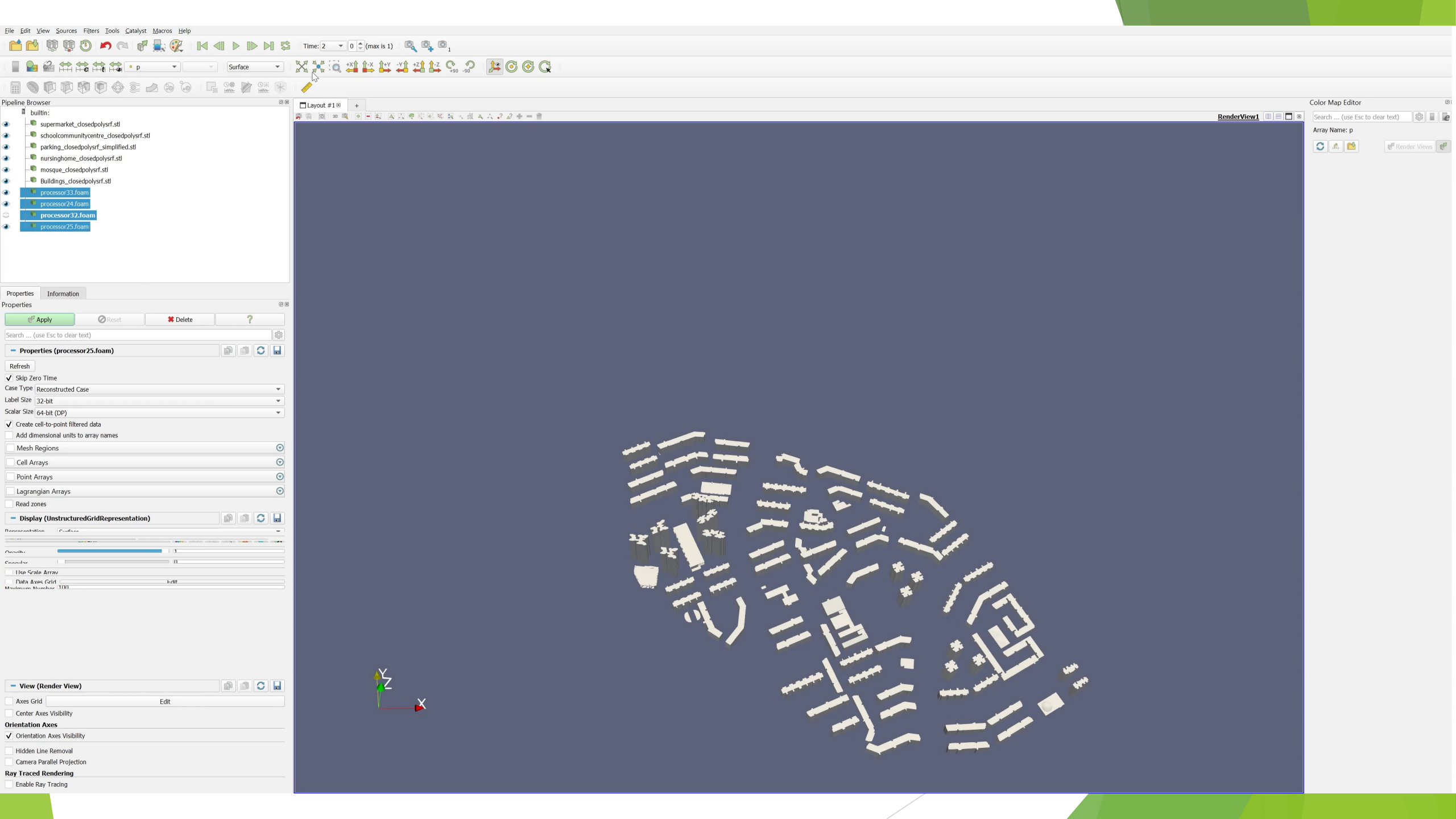
Why CFD's?

- Aerodynamics
- Flood Risk Assessment
- Wind Energy
- Urban Heat Sinks

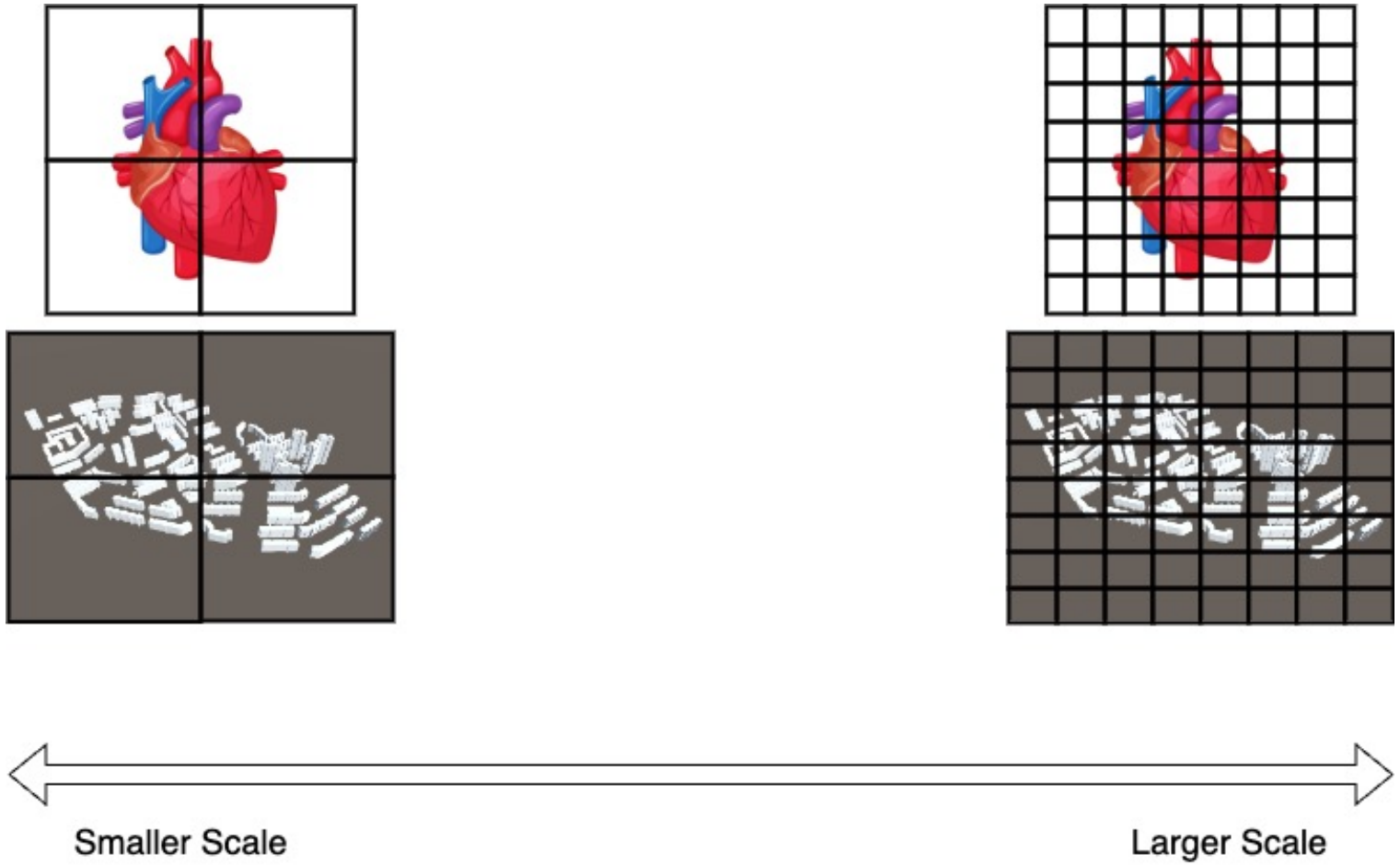


https://www.researchgate.net

Massive


File Edit View Sources Filters Tools Catalyst Macros Help
Time: 2 0 (max is 1)
Surface
Pipeline Browser
builtin:
supermarket_closedpolysrf.stl
schoolcommunitycentre_closedpolysrf.stl
parking_closedpolysrf_simplified.stl
nursinghome_closedpolysrf.stl
mosque_closedpolysrf.stl
Buildings_closedpolysrf.stl
processor33.foam
processor24.foam
processor32.foam
processor25.foam
Properties
Information
Properties
Apply
Reset
Delete
Search ... (use Esc to clear text)
Properties (processor25.foam)
Refresh
Skip Zero Time
Case Type
Reconstructed Case
Label Size
32-bit
Scalar Size
64-bit (DP)
Create cell-to-point filtered data
Add dimensional units to array names
Mesh Regions
Cell Arrays
Point Arrays
Lagrangian Arrays
Read zones
Display (UnstructuredGridRepresentation)
View (Render View)
Axes Grid
Edit
Center Axes Visibility
Orientation Axes
Orientation Axes Visibility
Hidden Line Removal
Camera Parallel Projection
Ray Traced Rendering
Enable Ray Tracing
Layout #1
RenderView1
Color Map Editor
Search ... (use Esc to clear text)
Array Name: p
Render Views
Y
Z
X

CFD Scale



Current Issue

- Massive datasets do not fit into memory
- Manual loading of data in and out of memory
- Unclear which data represents a specific area

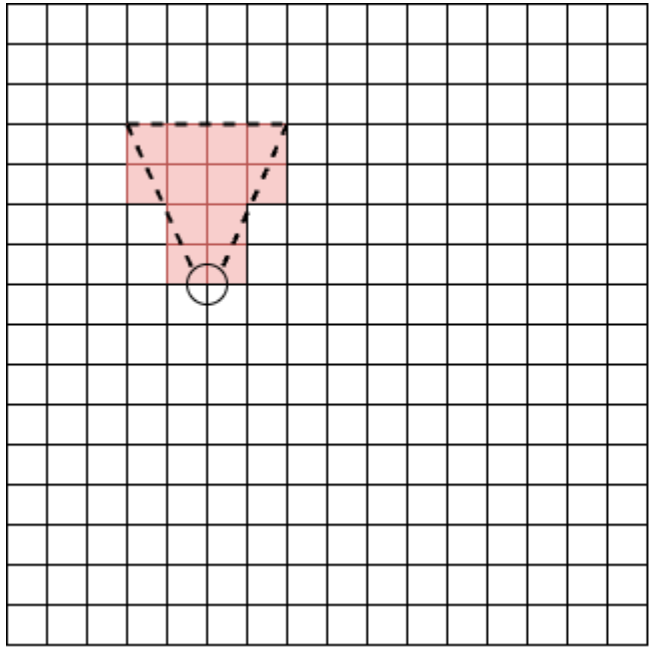
Research Question

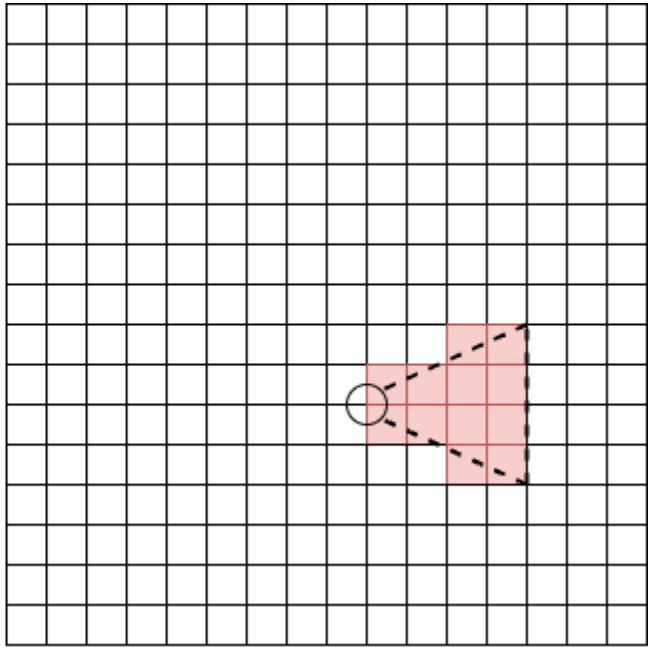
“ Can massive CFD results be visualized in Game Engines in real-time while presenting valuable information?”

Proposed Solution

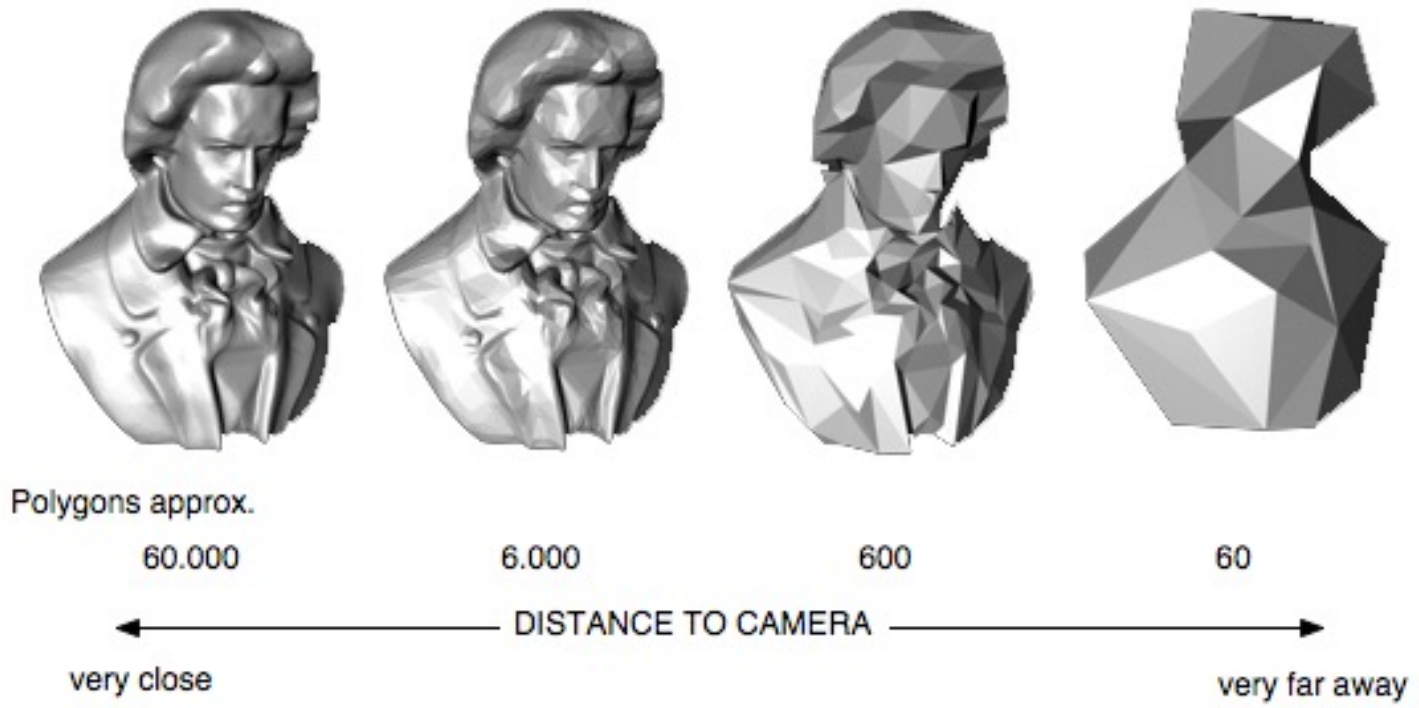
- Automate Data Loading
  - No human interaction required
- Level of Detail
  - Provide detail based on user distance
- Game Engines

Dynamic Loading



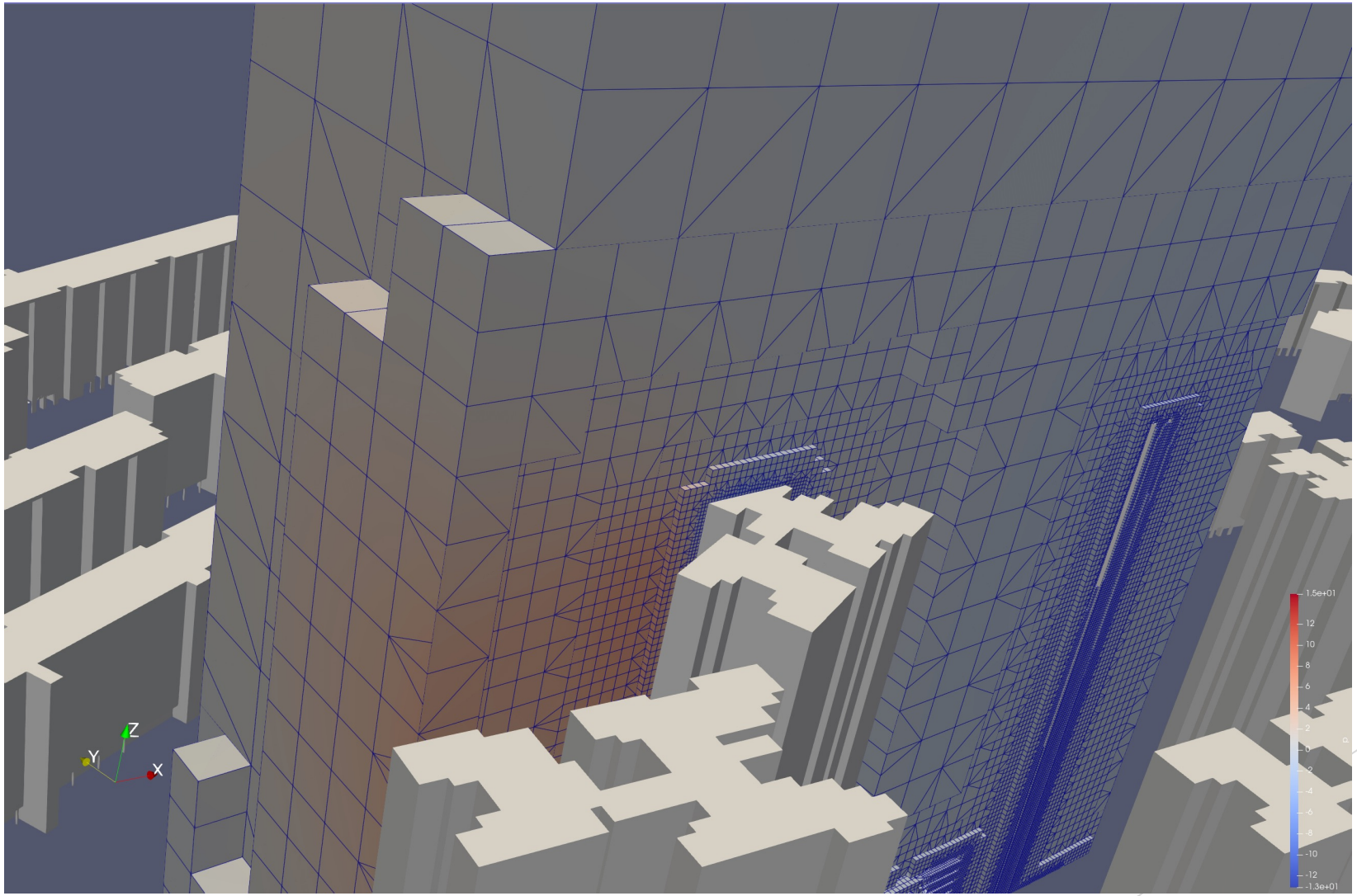


Level of Detail (LoD)



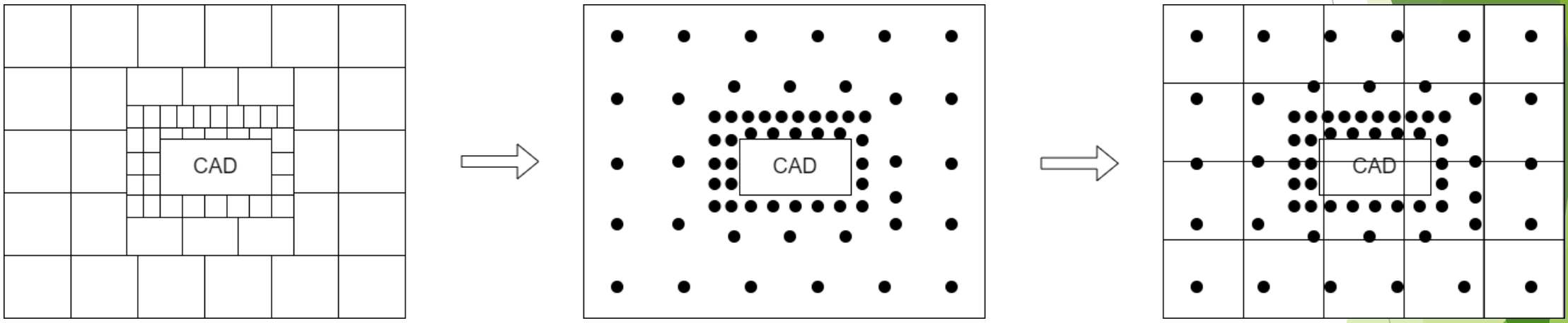
https://gamedev.stackexchange.com

Pre-Processing

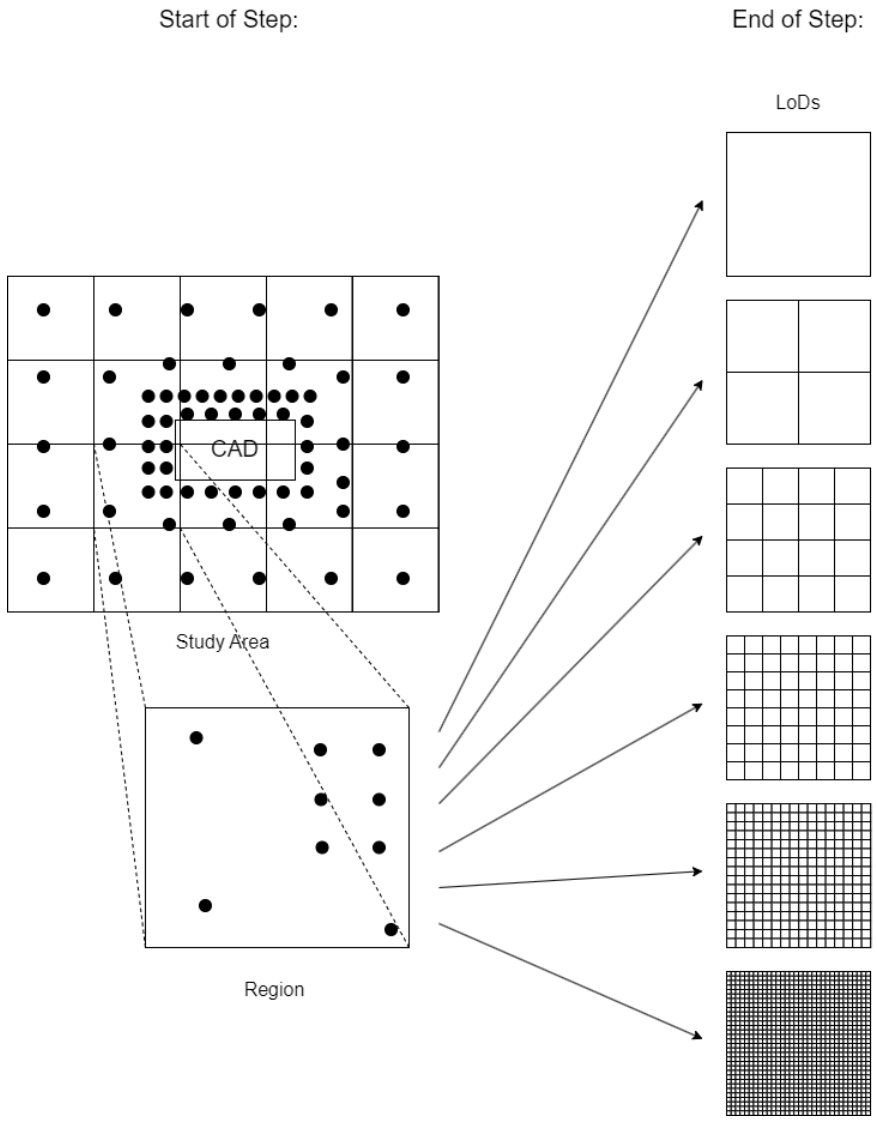


Generating Regions

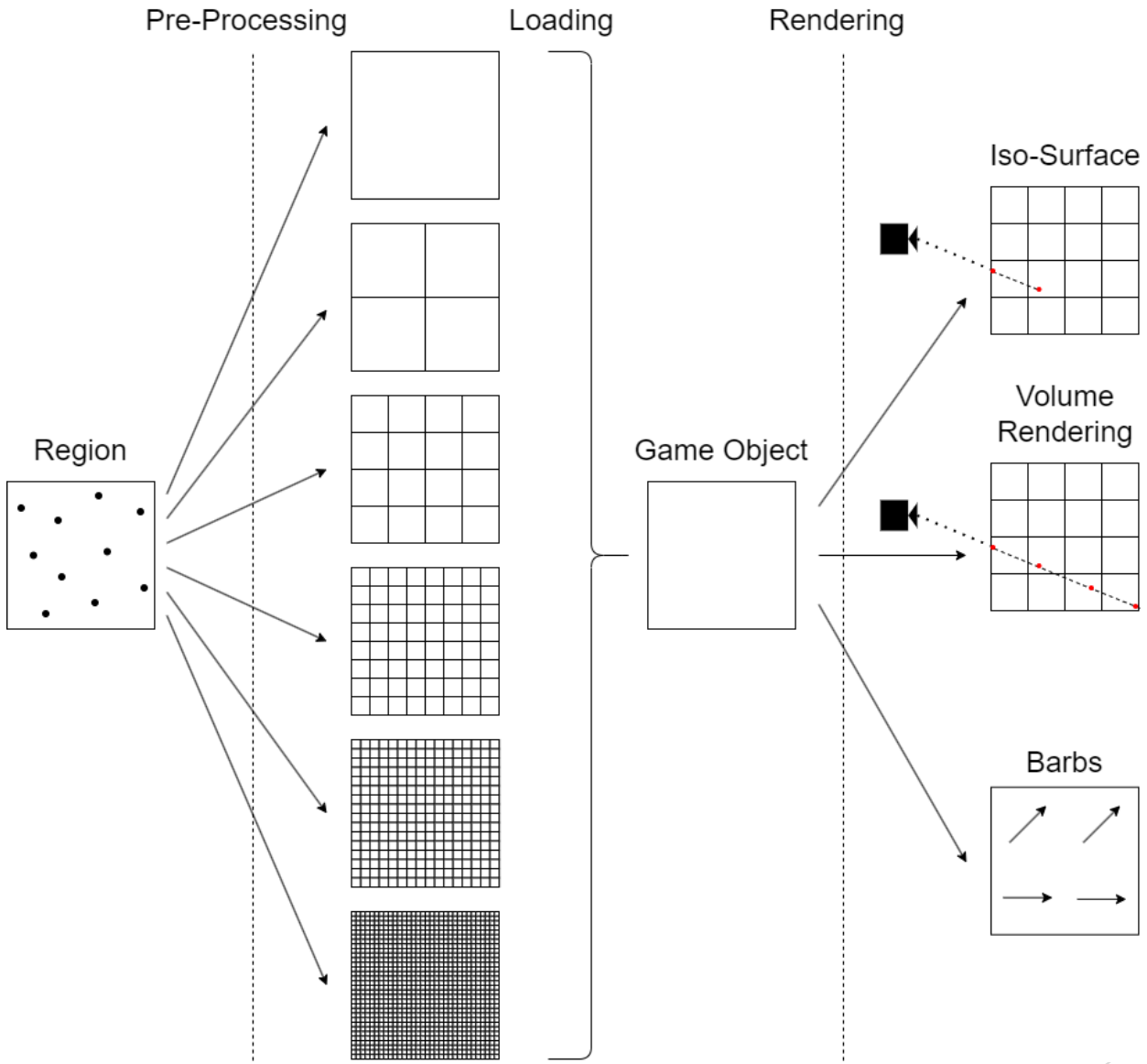
Entire Study Area



Generating LoDs

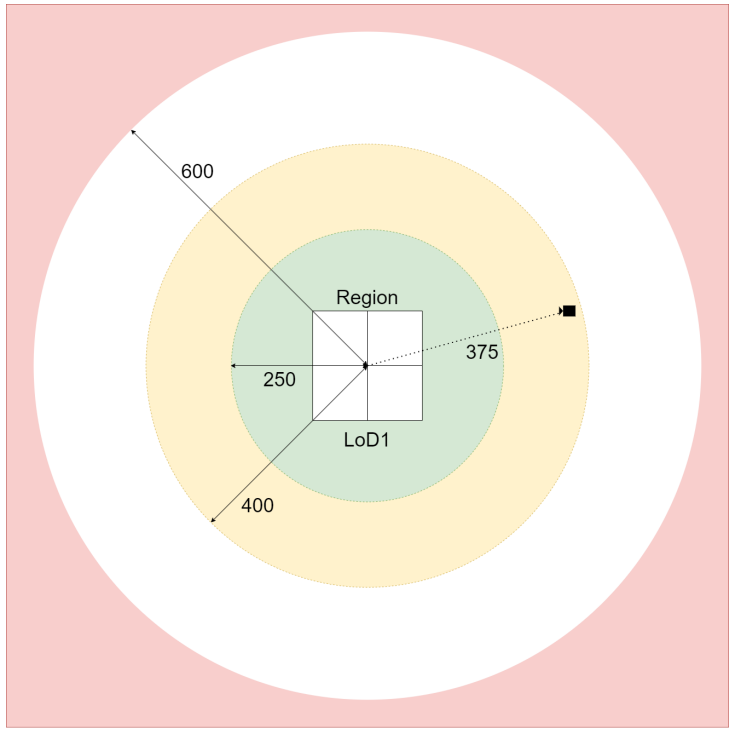


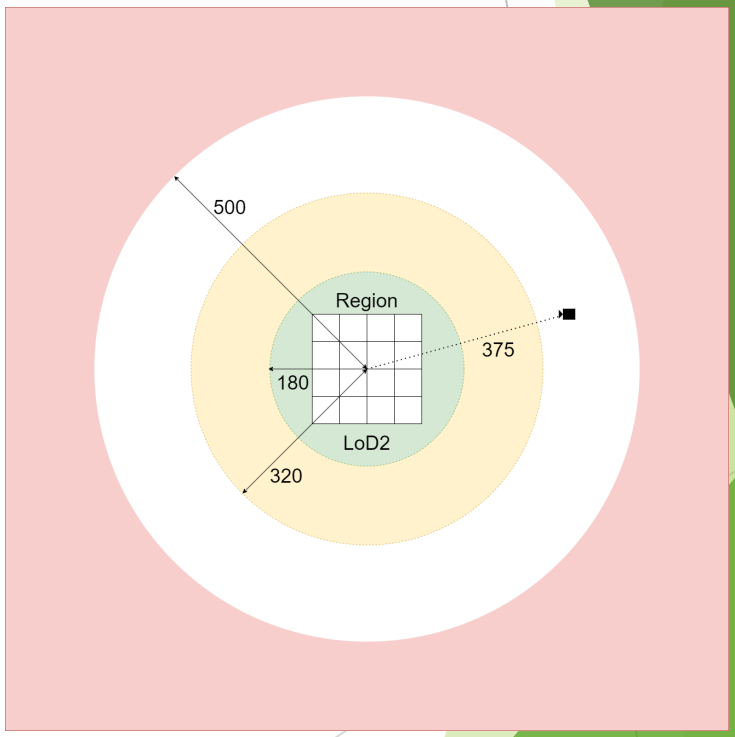
Visualization



LoD loaded for Regions

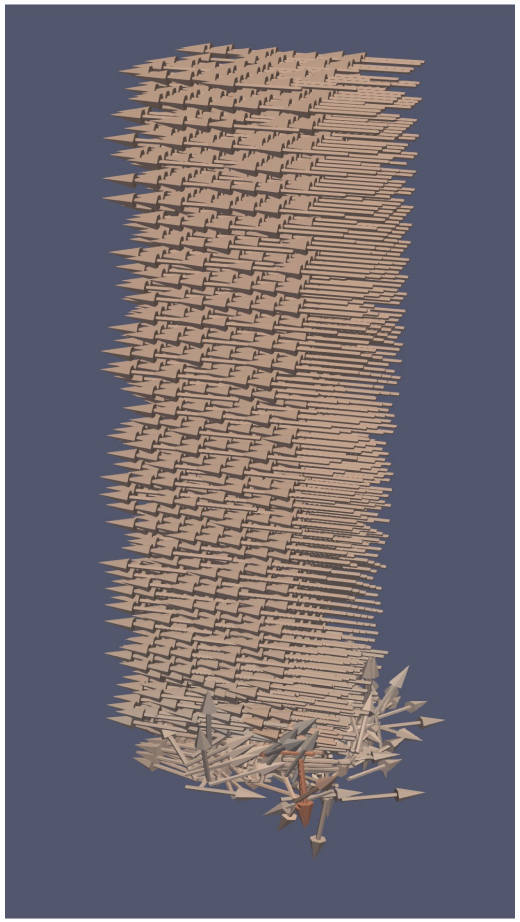
- Visualize
- Load
- Unload



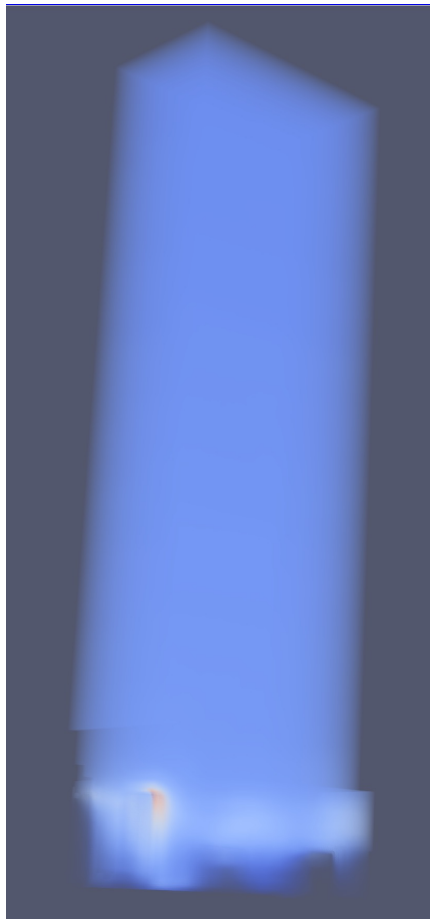


Visualization Techniques

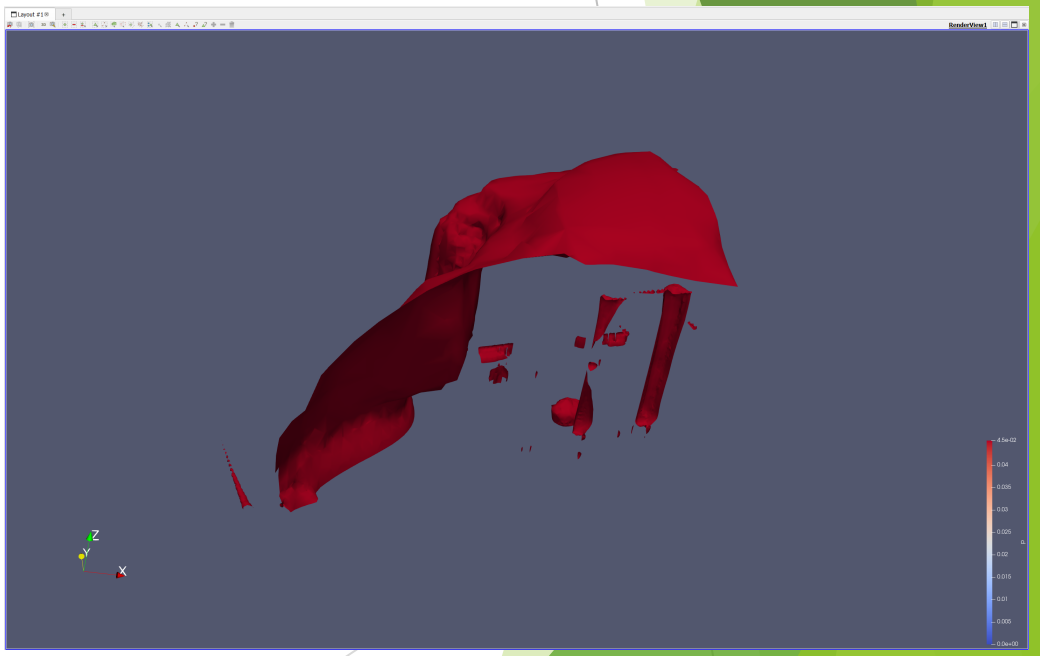
Barbs



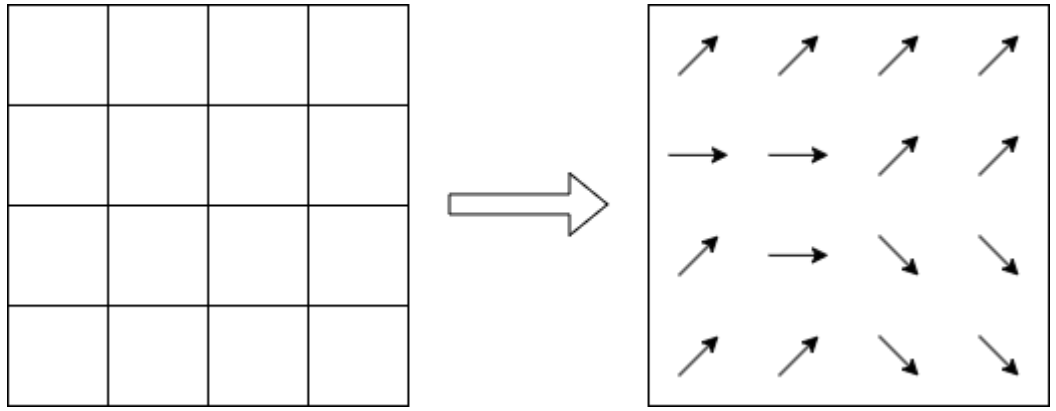
Volume Rendering

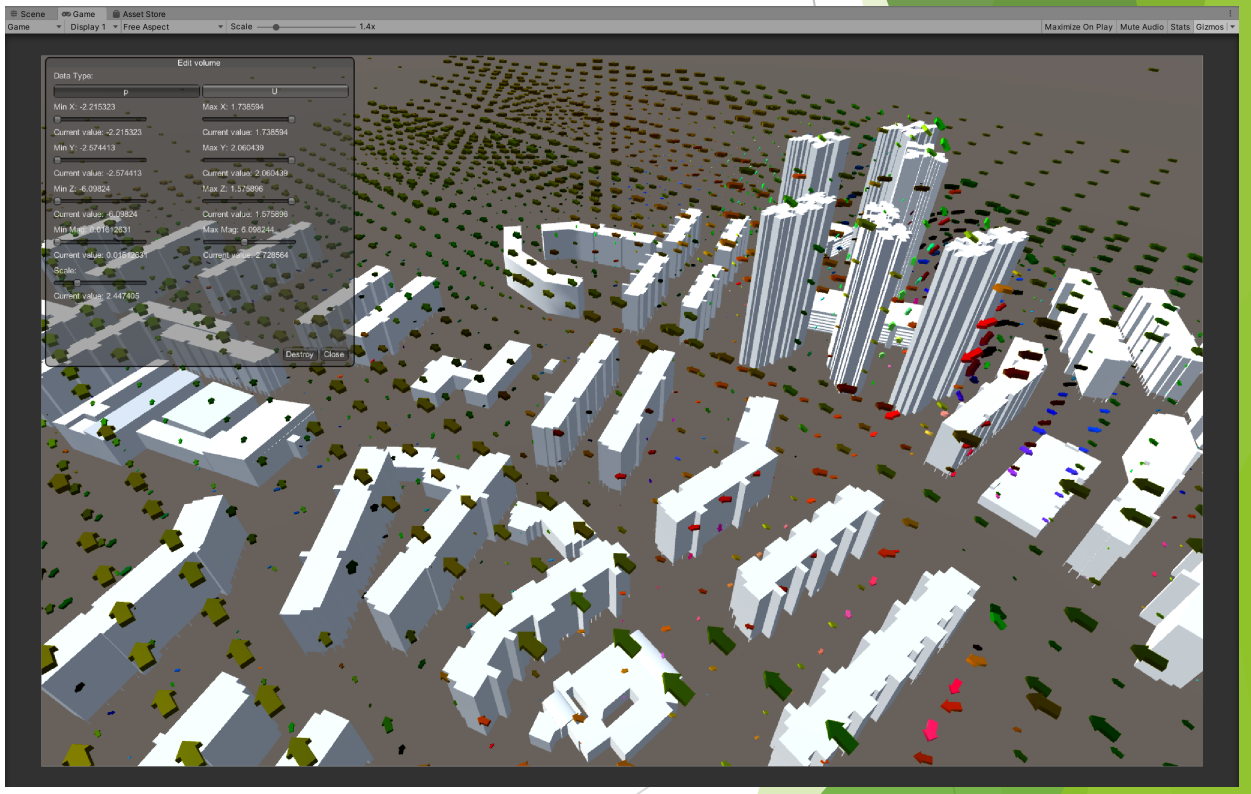


Iso-surface Rendering



Barbs





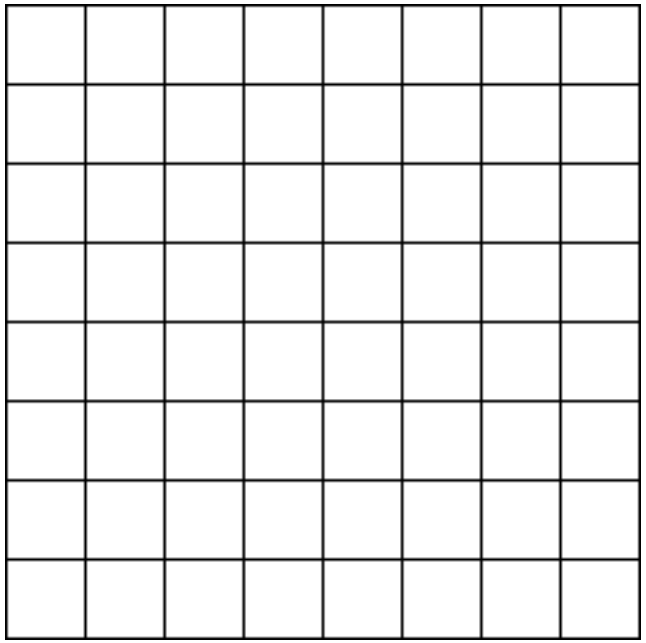
Volume and Iso-surface rendering in Game Engines

- Textures & Shader

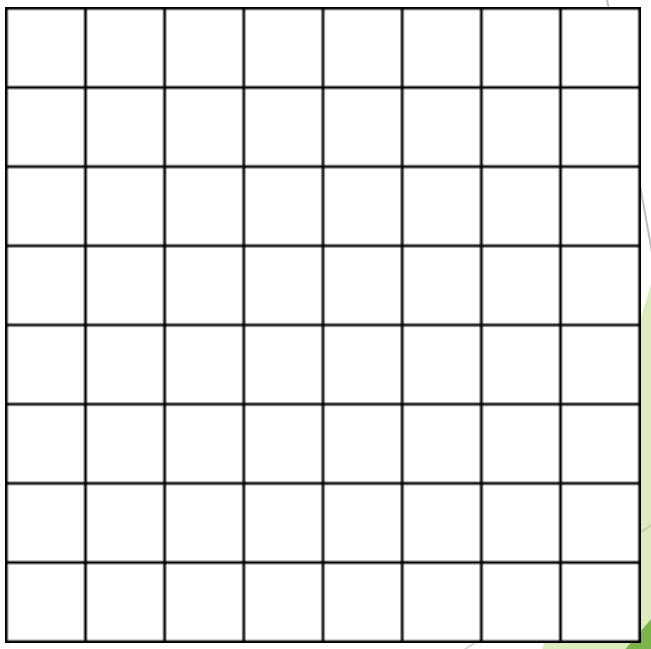
0.5	0.6	0.7	0.1	0.2	0.5	0.3	0.5
0.5	0.4	0.5	0.5	0.5	0.5	0.5	0.5
0.5	0.2	0.5	0.5	0.3	0.5	0.5	0.5
0.4	0.1	0.5	0.5	0.4	0.8	0.5	0.8
0.7	0.9	0.5	0.5	0.6	0.5	0.9	0.7
0.5	0.8	0.3	0.5	0.5	0.6	0.5	0.5
0.5	0.2	0.5	0.9	0.4	0.4	0.5	0.4
0.2	0.1	0.5	0.5	0.4	0.5	0.3	0.5

Creating Textures

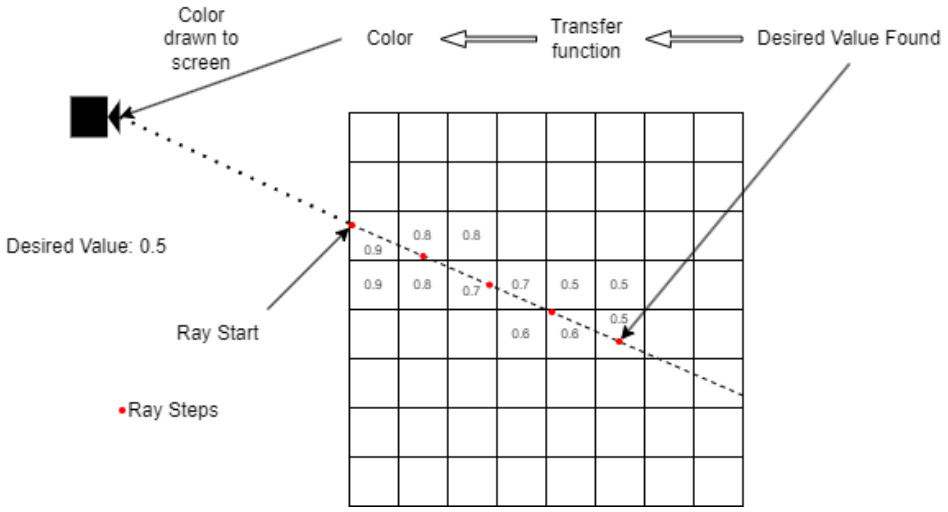
LoD 3

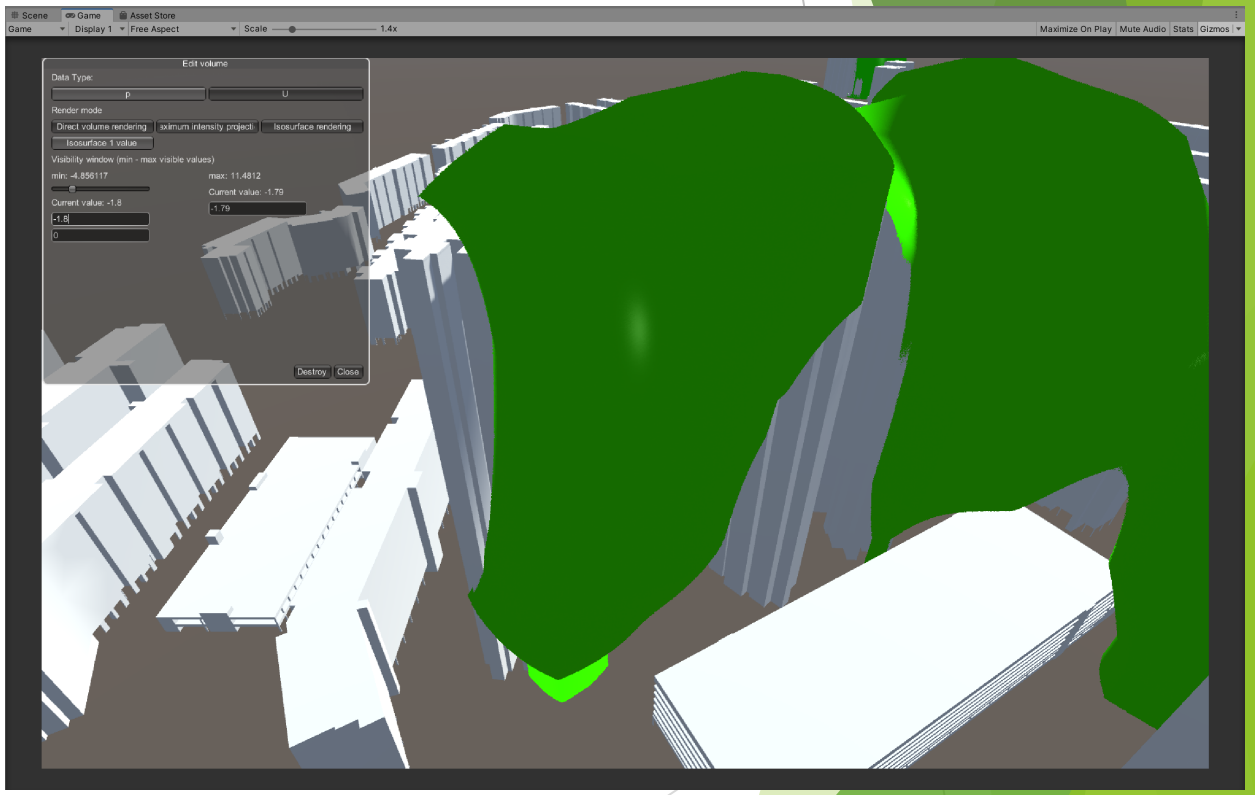


8x8 Texture

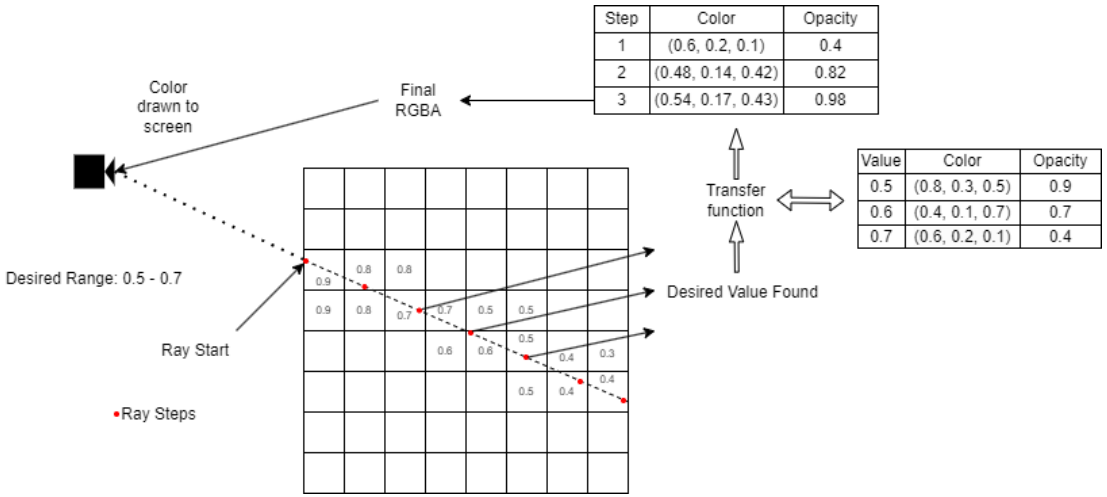


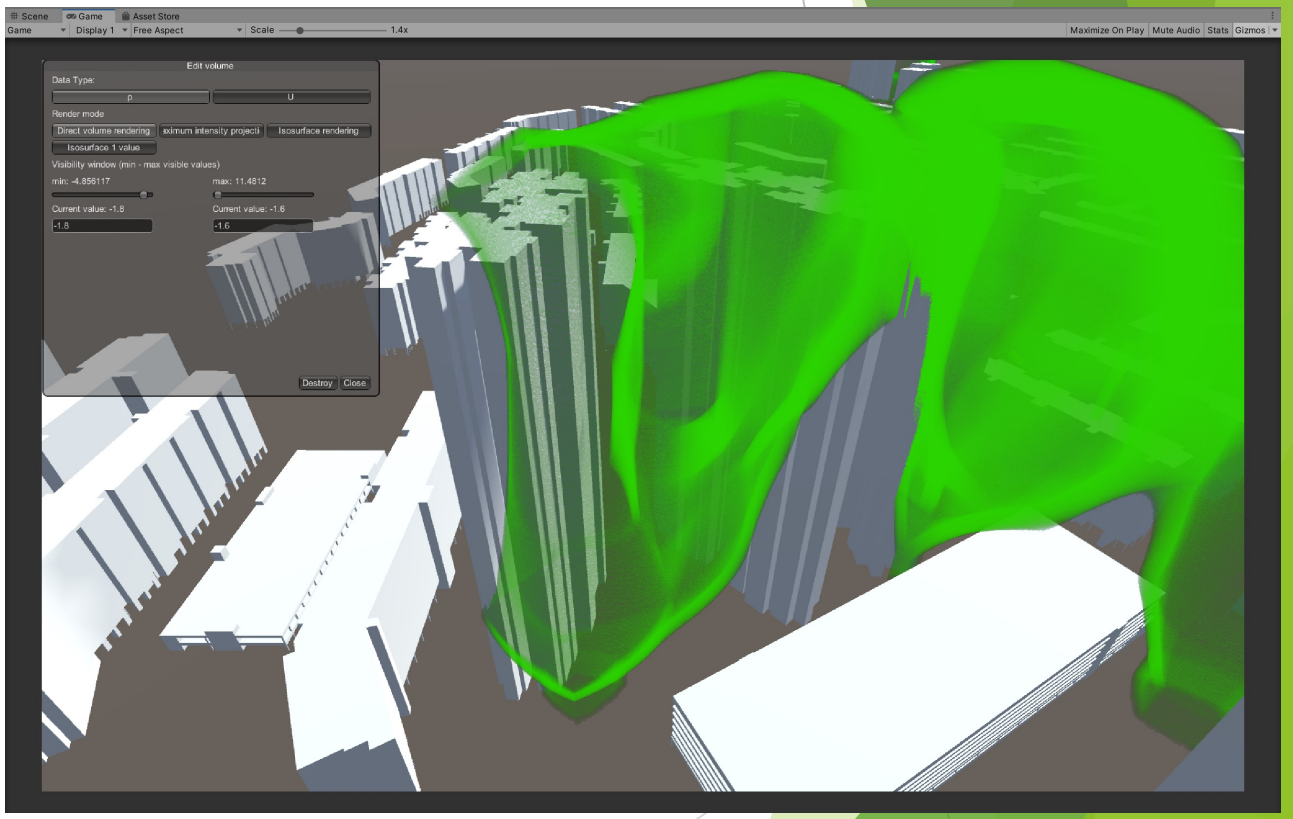
Iso-surface

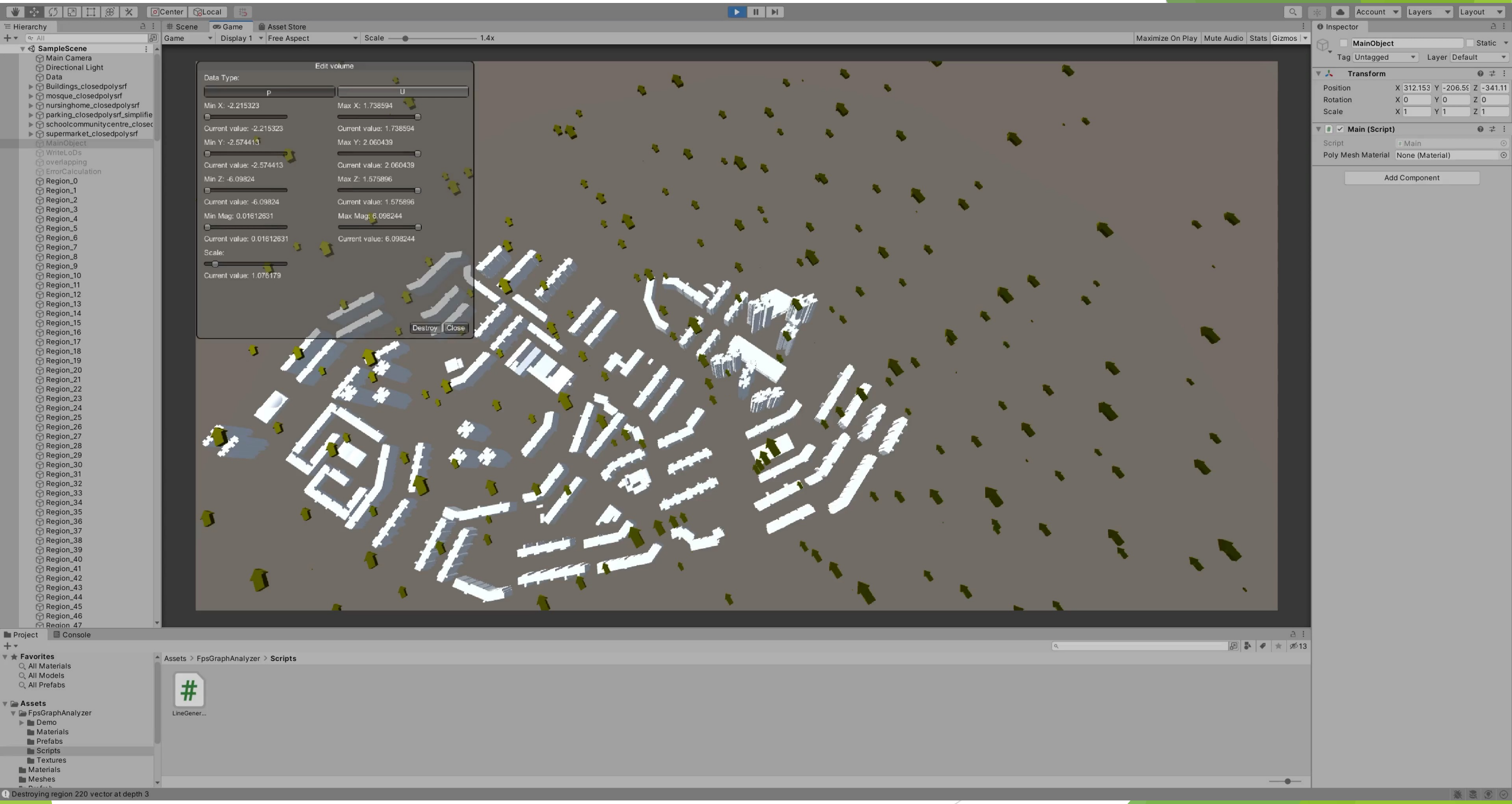

Color drawn to screen
Color
Transfer function
Desired Value Found
Desired Value: 0.5
Ray Start
Ray Steps
0.9
0.8
0.8
0.9
0.8
0.7
0.7
0.5
0.5
0.6
0.6
0.5


Scene
Game
Asset Store
Edit volume
Data Type:
Render mode
Direct volume rendering
Isosurface rendering
Visibility window (min - max visible values)
Destroy
Close

Volume Rendering






Edit volume
Data Type:
p
U
Min X: -2.215323
Max X: 1.738594
Current value: -2.215323
Current value: 1.738594
Min Y: -2.574413
Max Y: 2.060439
Current value: -2.574413
Current value: 2.060439
Min Z: -6.09824
Max Z: 1.575896
Current value: -6.09824
Current value: 1.575896
Min Mag: 0.01612631
Max Mag: 6.098244
Current value: 0.01612631
Current value: 6.098244
Scale:
Current value: 1.076179
Destroy
Close
Hierarchy
SampleScene
Main Camera
Directional Light
Data
Buildings_closedpolysrf
mosque_closedpolysrf
nursinghome_closedpolysrf
parking_closedpolysrf_simplifie
schoolcommunitycentre_closed
supermarket_closedpolysrf
MainObject
WriteLoDs
overlapping
ErrorCalculation
Region_0
Region_1
Region_2
Region_3
Region_4
Region_5
Region_6
Region_7
Region_8
Region_9
Region_10
Region_11
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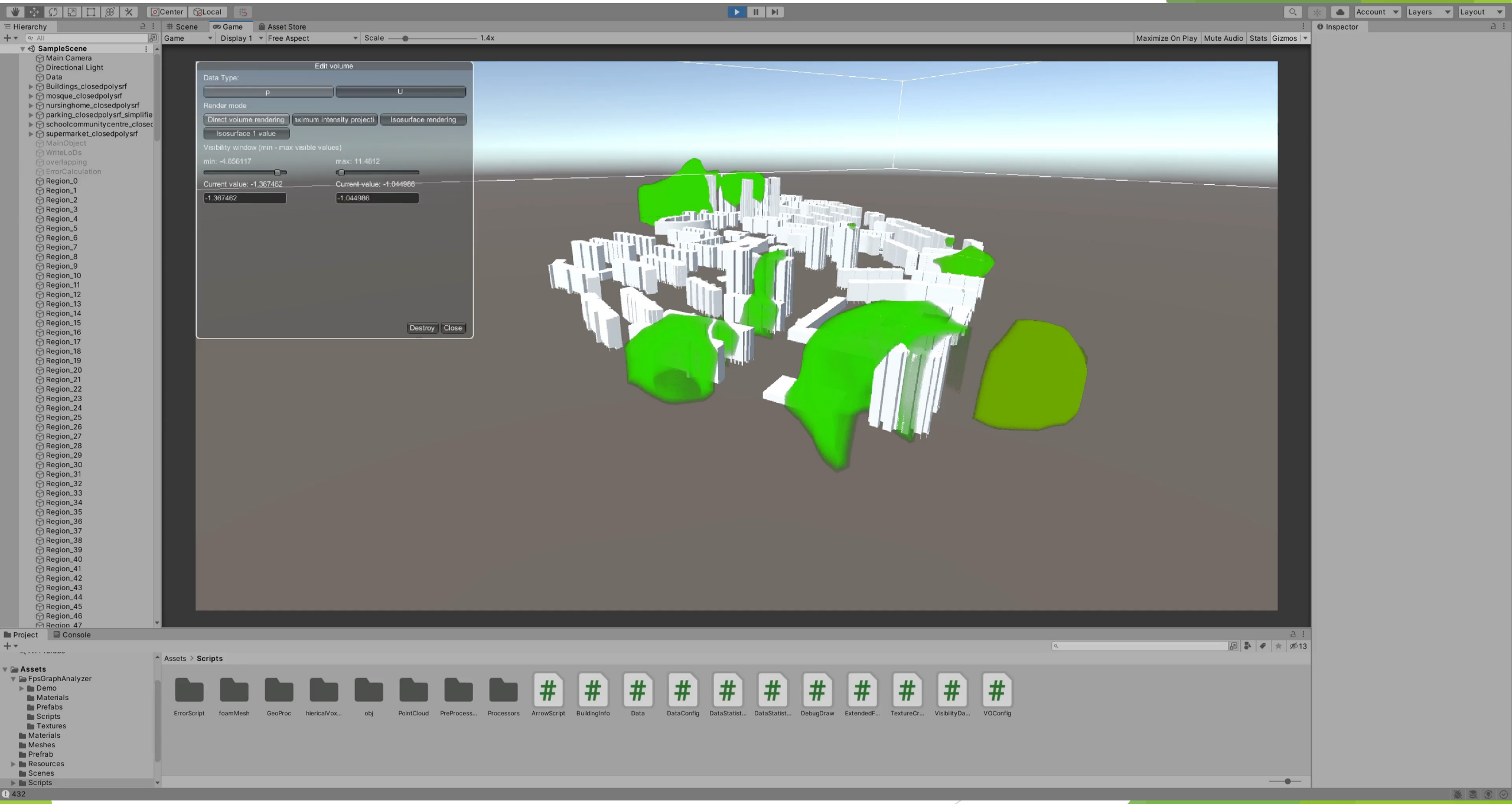
Region_45
Region_46
Region_47
Scene
Game
Asset Store
Game
Display 1
Free Aspect
Scale
1.4x
Maximize On Play
Mute Audio
Stats
Gizmos
Inspector
MainObject
Static
Tag
Untagged
Layer
Default
Transform
Position
Rotation
Scale
Main (Script)
Script
Main
Poly Mesh Material
None (Material)
Add Component
Project
Console
Favorites
All Materials
All Models
All Prefabs
Assets
FpsGraphAnalyzer
Demo
Materials
Prefabs
Scripts
Textures
Materials
Meshes
Assets
FpsGraphAnalyzer
Scripts
LineGener...
Destroying region 220 vector at depth 3


Edit volume
Data Type:
p
U
Render mode
Direct volume rendering
aximum intensity projecti
Isosurface rendering
Isosurface 1 value
Visibility window (min - max visible values)
min: -4.856117
max: 11.4612
Current value: -1.367462
Current value: -1.044986
-1.367462
-1.044986
Destroy
Close
Hierarchy
Scene
Game
Asset Store
Inspector
Project
Console
Assets
Scripts
SampleScene
Main Camera
Directional Light
Data
Buildings_closedpolysrf
mosque_closedpolysrf
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MainObject
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Region_0
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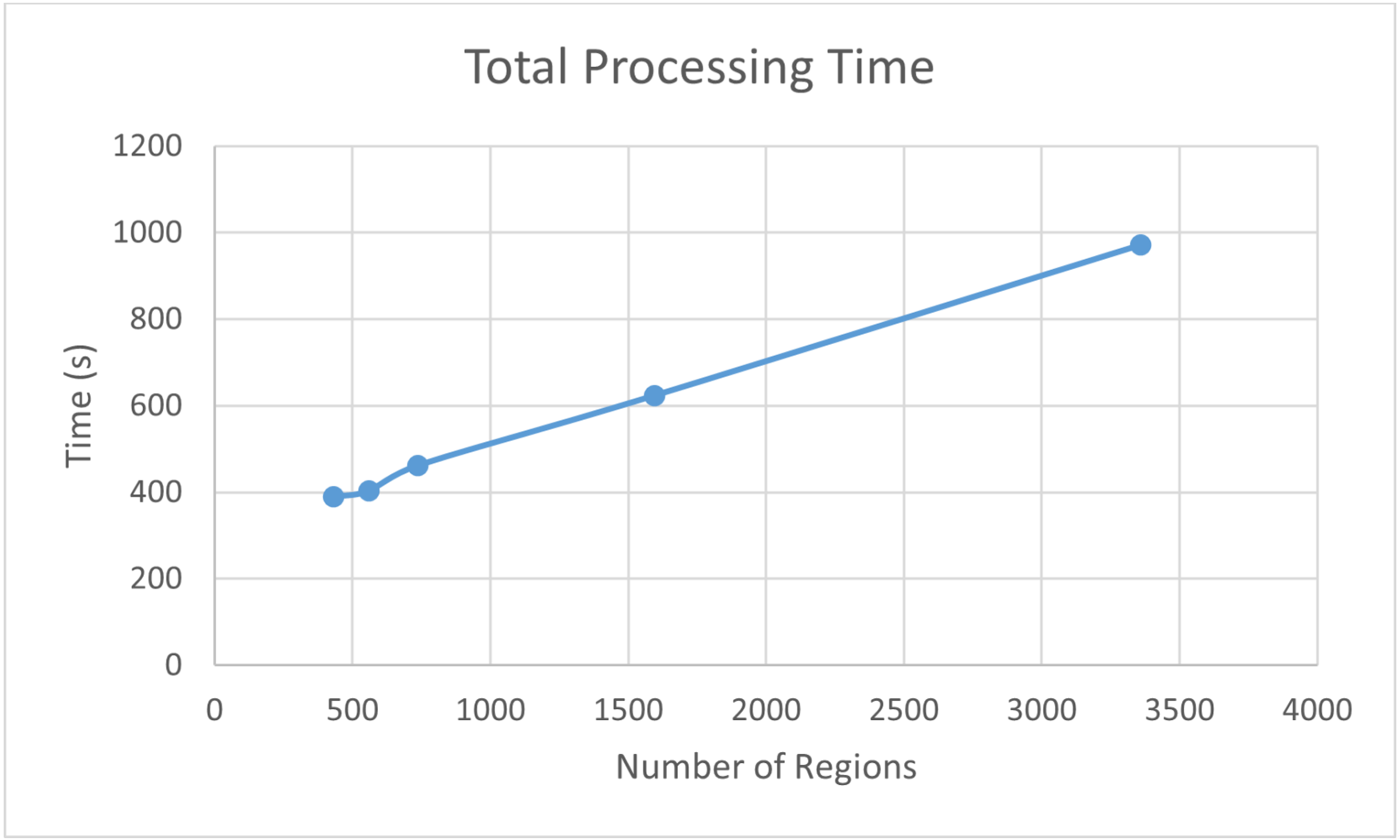
Region_47
FpsGraphAnalyzer
Demo
Materials
Prefabs
Scripts
Textures
Materials
Meshes
Prefrab
Resources
Scenes
Scripts
ErrorScript
foamMesh
GeoProc
hiericalVox...
obj
PointCloud
PreProcess...
Processors
ArrowScript
BuildingInfo
Data
DataConfig
DataStatist...
DataStatist...
DebugDraw
ExtendedF...
TextureCr...
VisibilityDa...
VOConfig

Pre-Processing Time



Error

LoD	Average Pressure Error (%)	Pressure standard Deviation	Velocity Magnitude Error (%)	Velocity Magnitude standard deviation
0	23.42	0	92.61	0
1	15.11	0.13	35.11	0.14
2	14.05	0.33	24.31	0.12
3	77.76	161.91	2.96	0.11
4	1.55	4.56	1.14	0.37
5	6.50	121.93	0.42	0.03

LoD	Average Pressure Error (%)	Pressure standard Deviation	Velocity Magnitude Error (%)	Velocity Magnitude standard deviation
0	0.96	0	46.49	0
1	2.29	0.0009	25.58	0.06
2	2.68	0.0006	11.81	0.04
3	2.38	0.008	3.98	0.016
4	1.87	0.0092	1.70	0.0063
5	2.27	0.153	0.09	0.002

Limitations & Future Work

- Empty Voxel
- Cannot export visualized data
- None rectangular study areas

- Slicing
- Sub-regions
- Optimizations:
  - Number of regions
  - Number of LoDs
  - Load, render and destroy distance

Conclusion

Game Engines are capable to visualize massive CFD simulations in real time

Thank you!