DIGITAL DOMAIN®

OPENVDB ADOPTION

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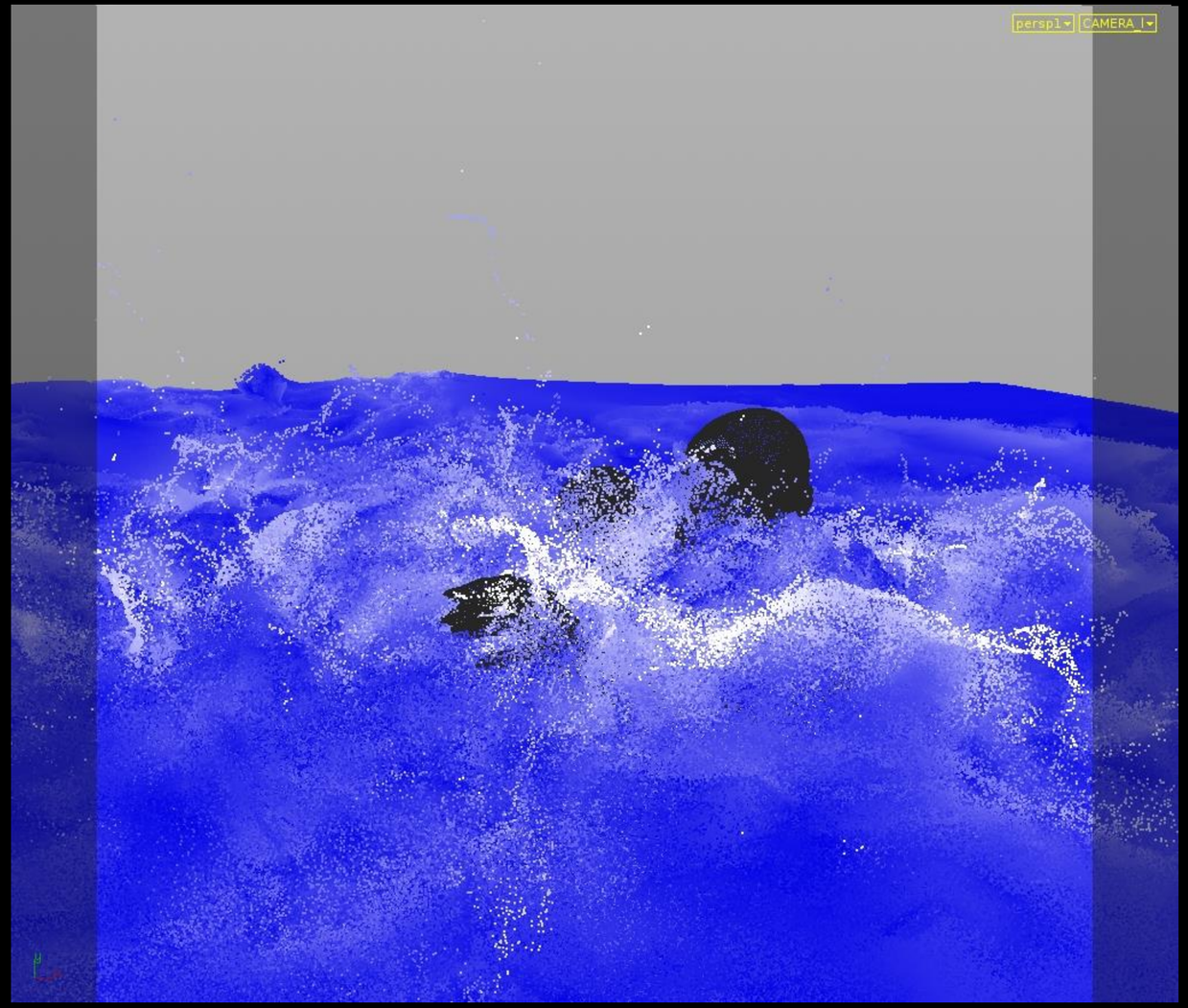
OUTLINE

- Introduction
- Fluid simulation
  - Workflow
  - Implementation
- Cloud advection
- Volume modeling

INTRODUCTION

- Cyclone
  - FX toolkit
  - Fluid simulation
  - Volume modeling
- Developed for three years
- Used in production the last year
  - Ender’s Game
  - Black Sky
  - Maleficent
  - Commercials

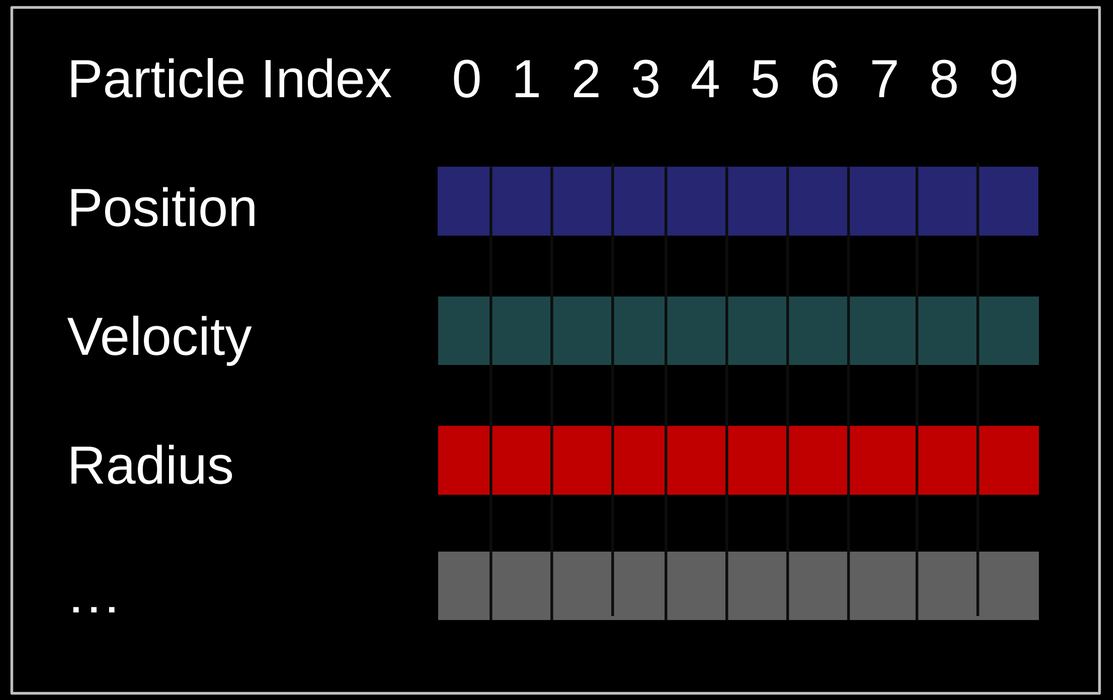


CYCLONE

- Specifically designed for sparse grids
  - Initially used DB-Grid [Museth, 2009]
  - Blocked data structure
  - Algorithms implemented to operate on blocks
  - Well suited for threading
  - Straightforward to replace with OpenVDB
- Integrated in Houdini

FLUID SIMULATION

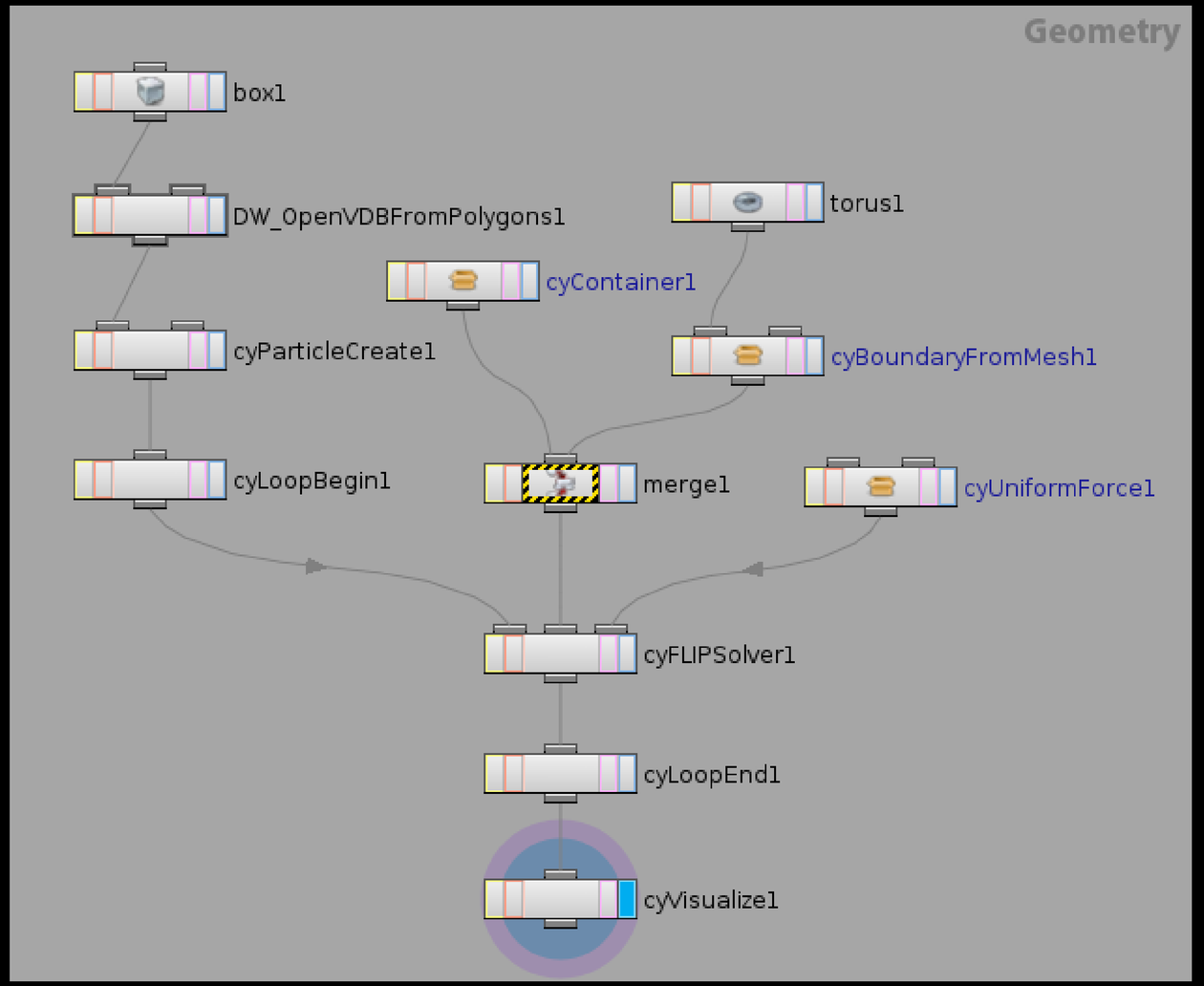
- FLIP Solver
  - Hybrid particle/grid solver
- Proprietary particle representation
  - Independent of third party package
  - Distributed simulations
- OpenVDB grid representation
  - Fluid surface (Level Set)
  - Fluid velocities (Staggered Vector grid)
  - Boundary objects, emitters, forces, sinks
  - Particle search acceleration



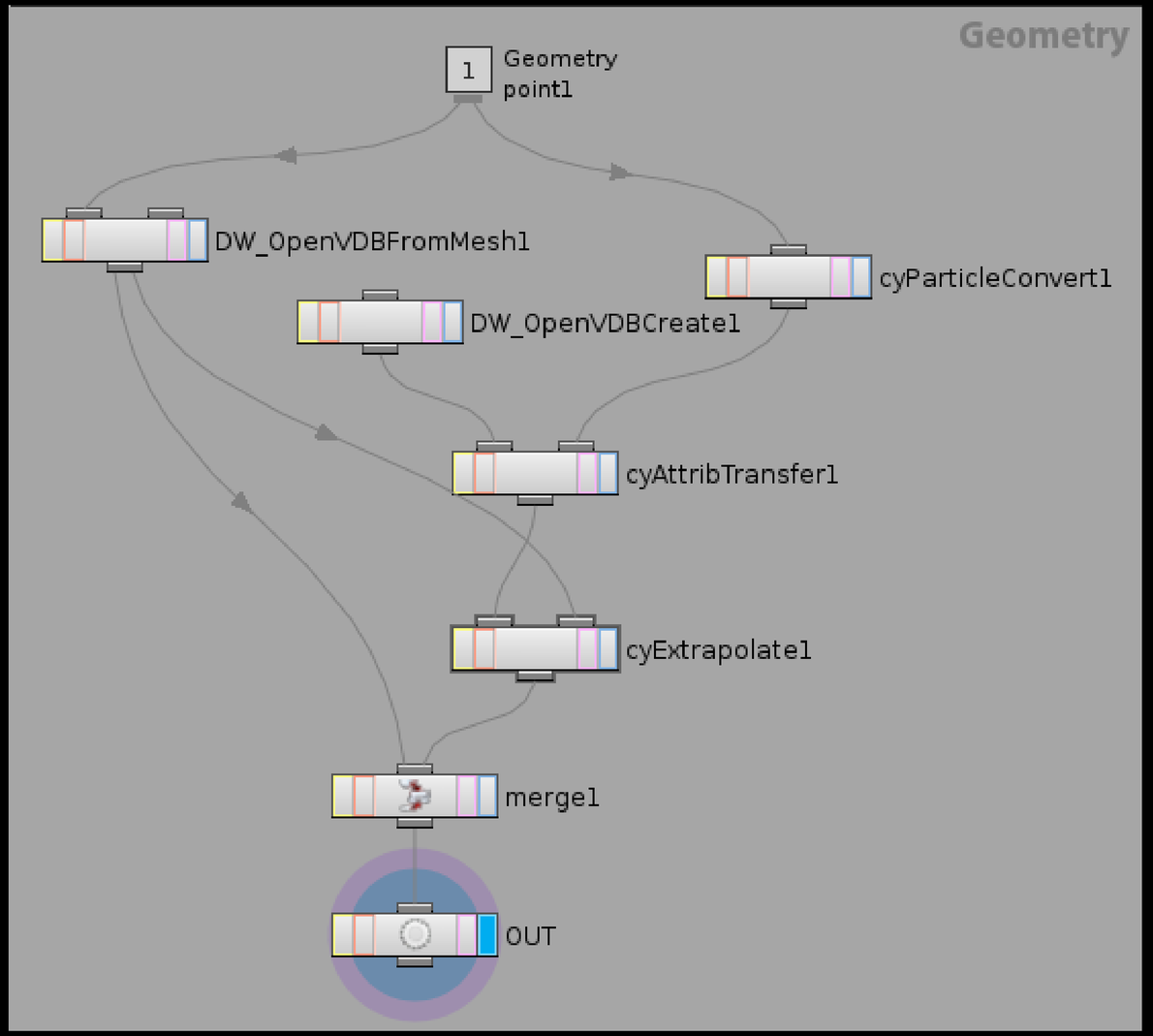
WORKFLOW

- SOP workflow preferred by artists
- Particle data passed as shared pointers
- Custom looping mechanism for simulations
- OTLs for fluid boundaries, forces etc

WORKFLOW


Geometry
box1
DW_OpenVDBFromPolygons1
torus1
cyContainer1
cyParticleCreate1
cyBoundaryFromMesh1
cyLoopBegin1
merge1
cyUniformForce1
cyFLIPSolver1
cyLoopEnd1
cyVisualize1

WORKFLOW


Geometry
1
Geometry
point1
DW_OpenVDBFromMesh1
cyParticleConvert1
DW_OpenVDBCreate1
cyAttribTransfer1
cyExtrapolate1
merge1
OUT

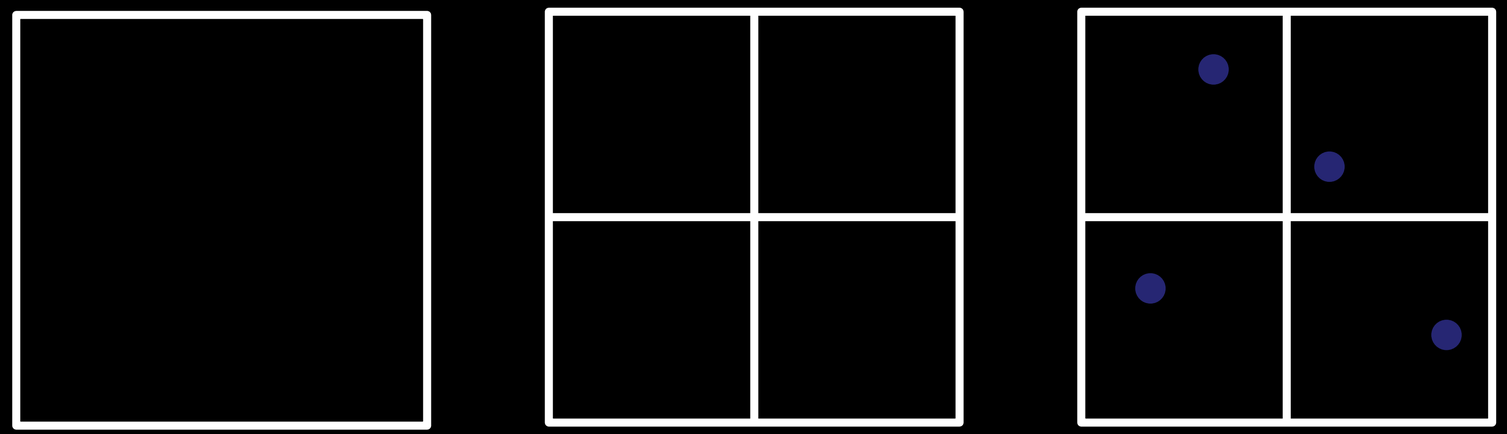
WORKFLOW

Additional SOPs

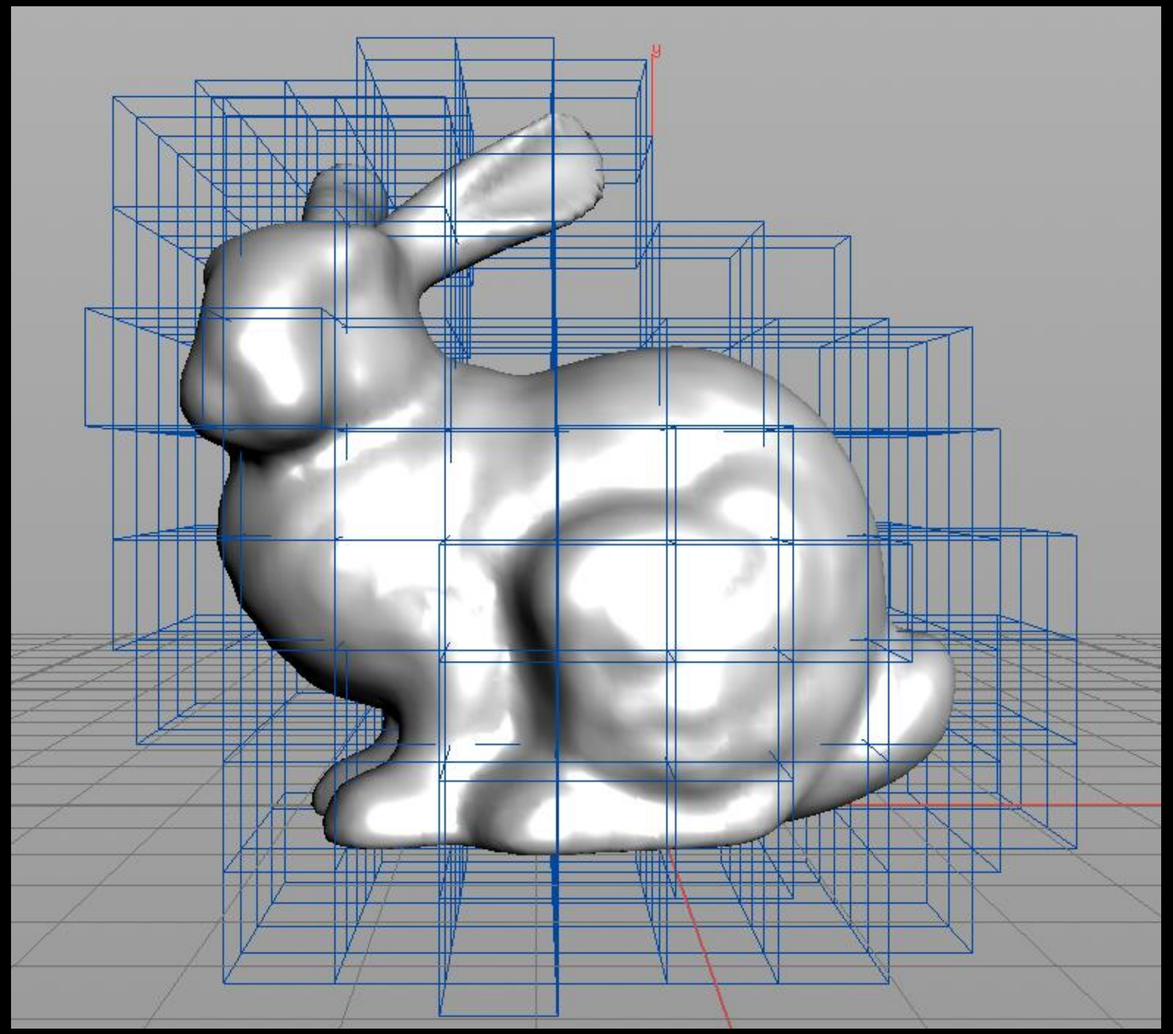
- Delete particles based on Level Set
- Advect particles and grids
- Surface particles

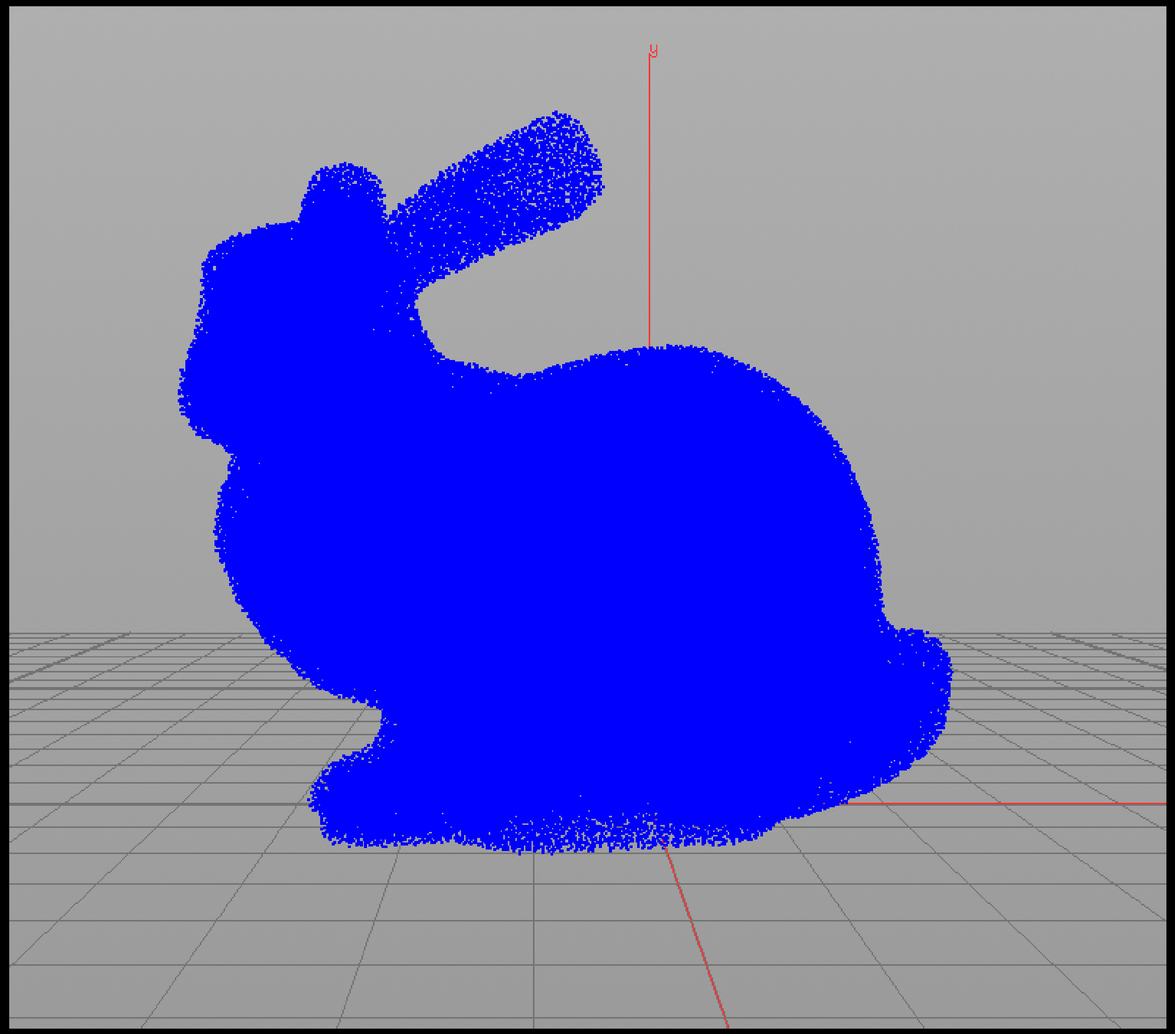
PARTICLE CREATION

- Use Level Set as guide
- Resample Level Set to sampling interval
- Create bool mask of inside region
- For each active voxel of mask
  - Subdivide voxel
  - Jitter particle position in sub voxel
  - Subdivision could be varied based on distance to surface



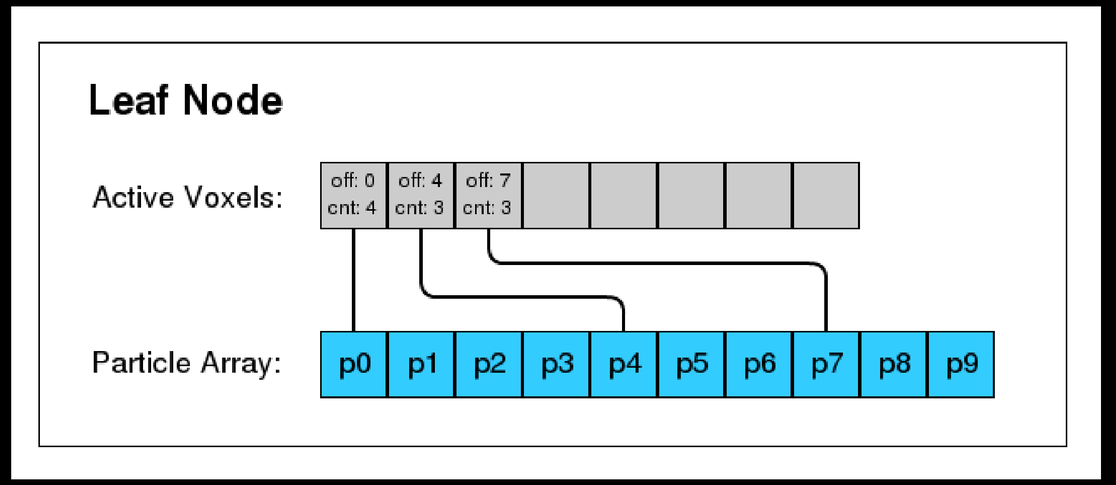
PARTICLE CREATION





PARTICLE GRID

- Accelerate particle search
  - KD-Tree, Hash table, Uniform grid
- Approach similar to [Nielsen el al., 2007]
- Extend Leaf Node with particle index array
- Store a Particle Bin per voxel
  - Two unsigned integers
  - Offset into index array
  - Number of particles

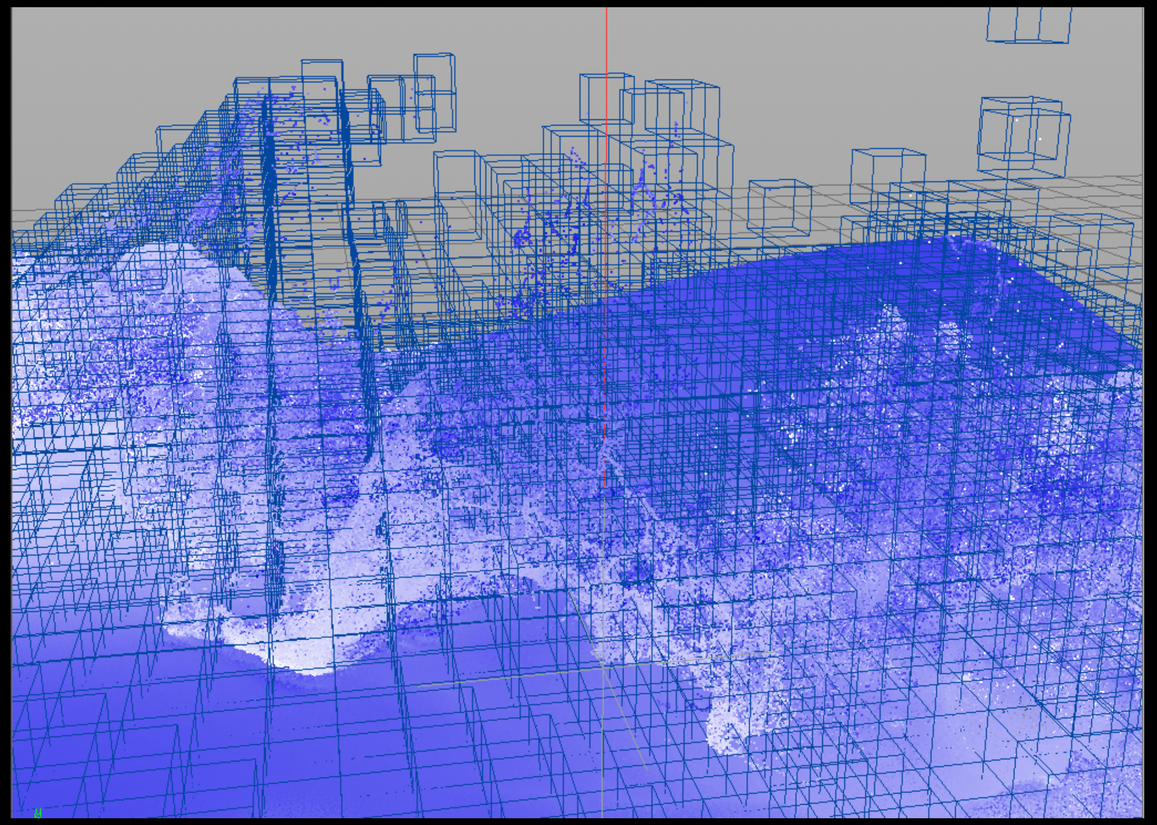


PARTICLE GRID

Build Grid

- For each particle
  - Compute voxel coordinate
  - Activate voxel
  - Increment particle counter for voxel
  - Store particle index in array
  - Store linear voxel offset in external array

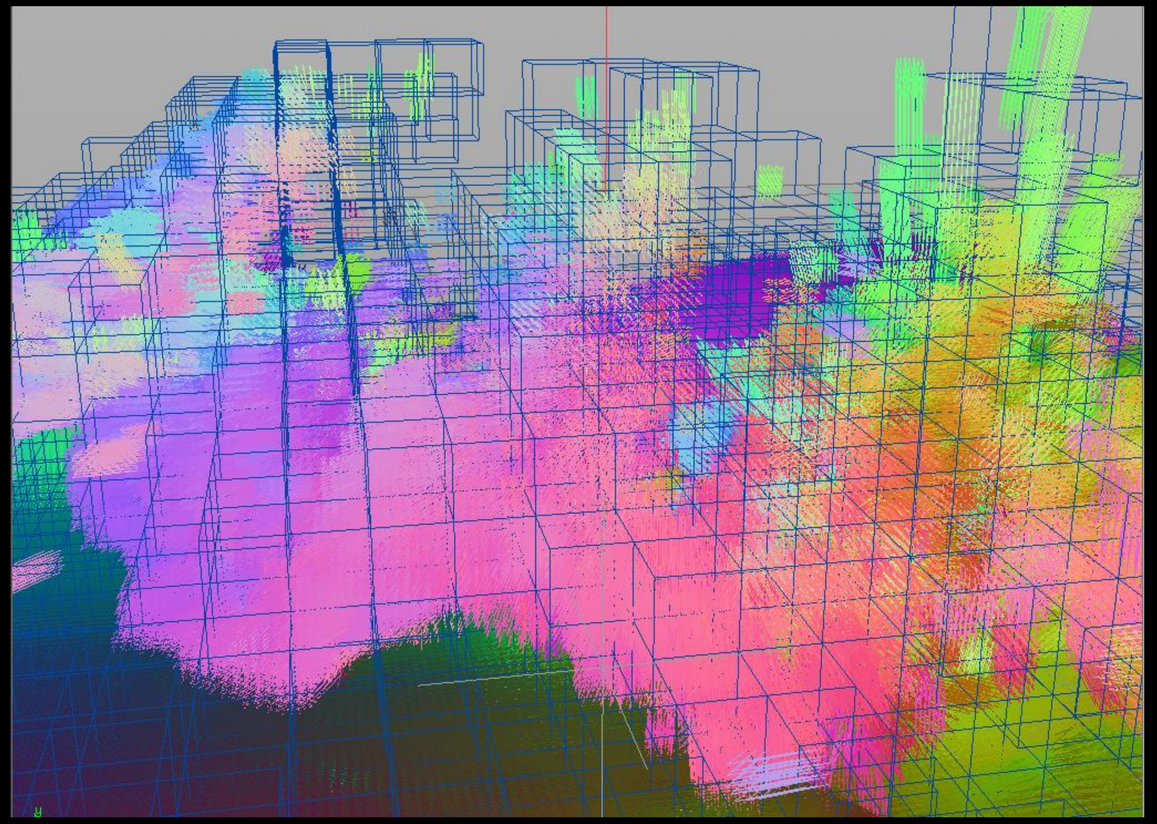
- For each Leaf Node
  - Sort index array based on voxel offset
  - For each active voxel
    - Update offset into index array



INTERPOLATION

- Interpolate particle attribute to grid
  - Velocity, density, viscosity etc.
- Weight value based on distance and kernel

- Initialize Particle Grid and copy topology
- Dilate topology based on weight radius
- For each active voxel
  - Find particles in neighborhood
  - Compute weighted value

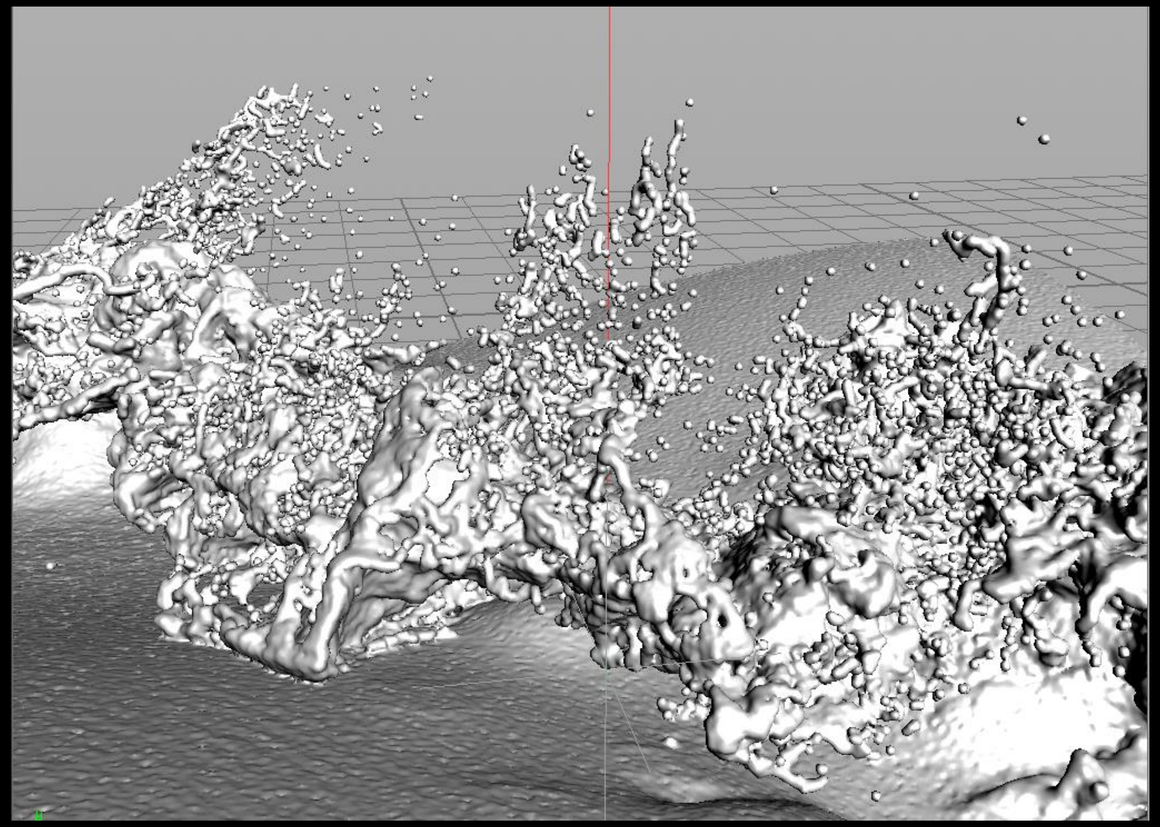


SURFACING

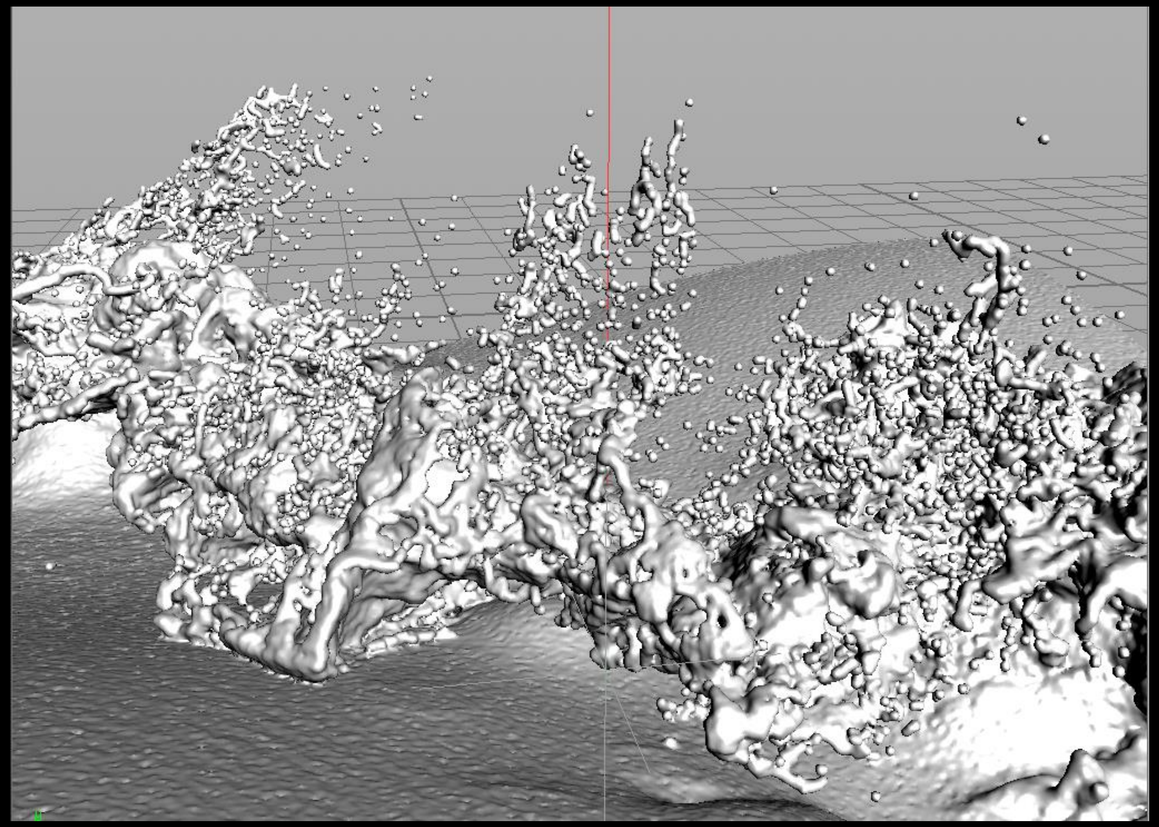
- Build Level Set from particles
  - Distance to closest particle
  - Weighted average of position and radius [Zhu and Bridson, 2005]
- Only interested in particles near the surface

- Initialize Particle Grid and copy topology
- Dilate and erode topology by weight radius
- Compute morphological difference and use to allocate grid
- For each active voxel
  - Find particles in neighborhood
  - Compute signed distance value
- Signed Flood Fill

SURFACING



Cyclone Surfacer (Closest distance)



OpenVDB From Particles

18.3 Million particles, Surface grid 2x resolution, No post processing

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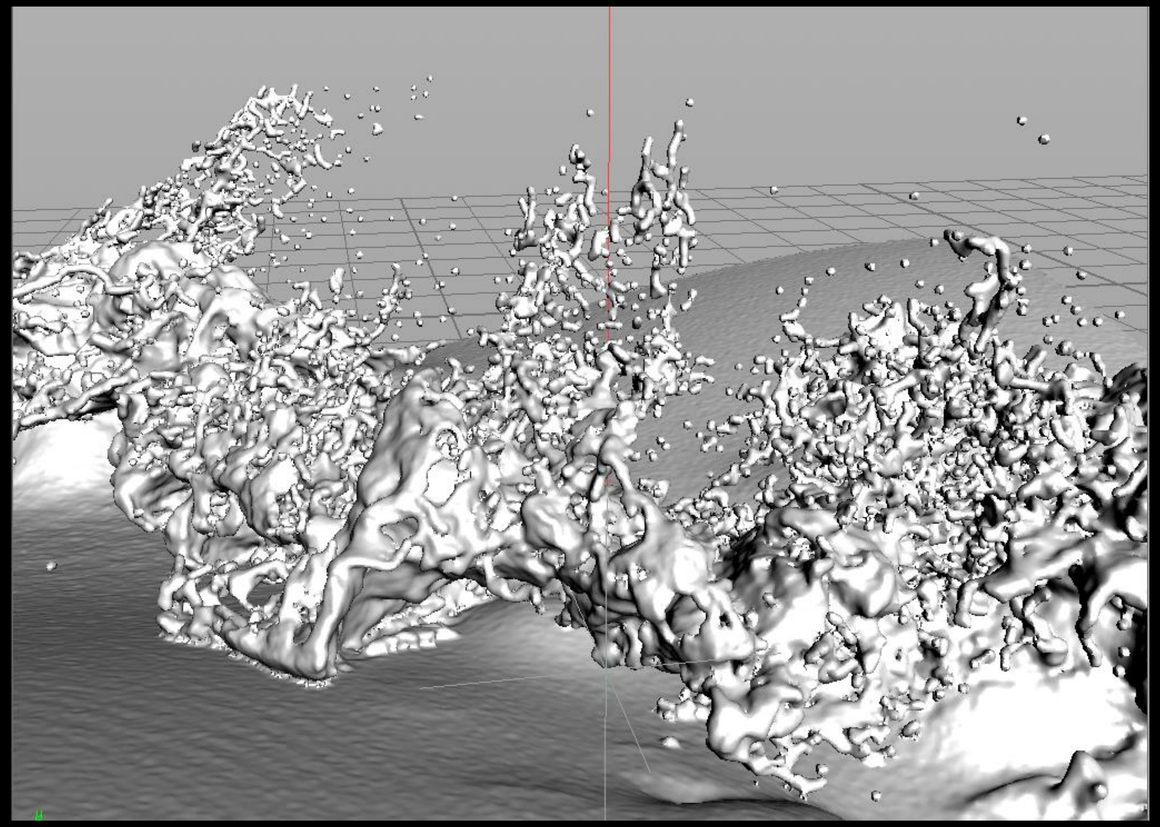
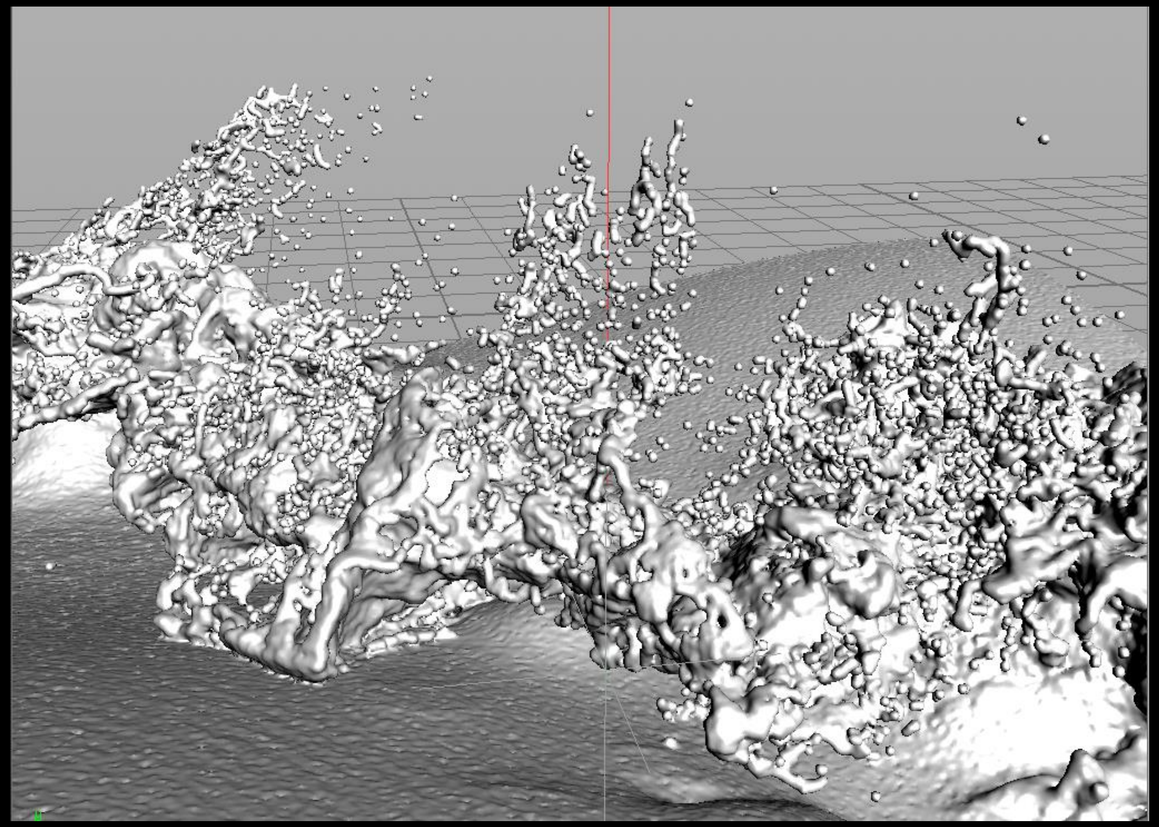
SURFACING



Cyclone Surfacer (Weighted average)



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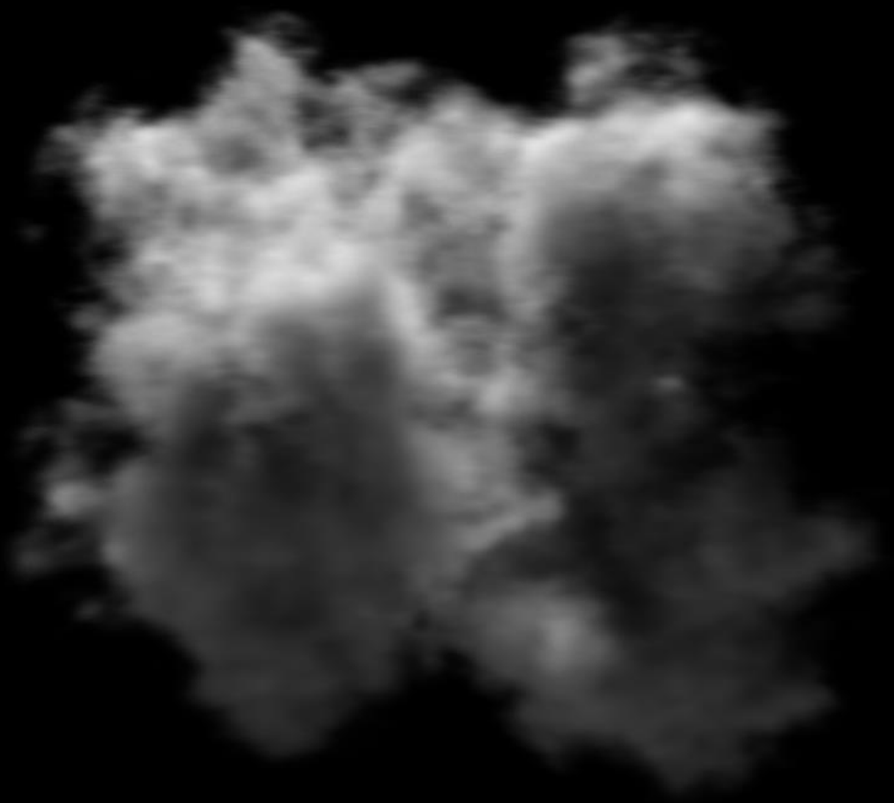
CLOUD ADVECTION

- Problem:
  - Animate clouds with rotational motion
- Advect density grid in forcefield
- Model forcefield using animated points
  - Interpolate point velocities to grid
- Semi-Lagrangian advection
  - Too much numerical dissipation
- Particle based density advection
  [Wrenninge et al., 2011]
- Built advection tool as OTL using Cyclone and OpenVDB nodes



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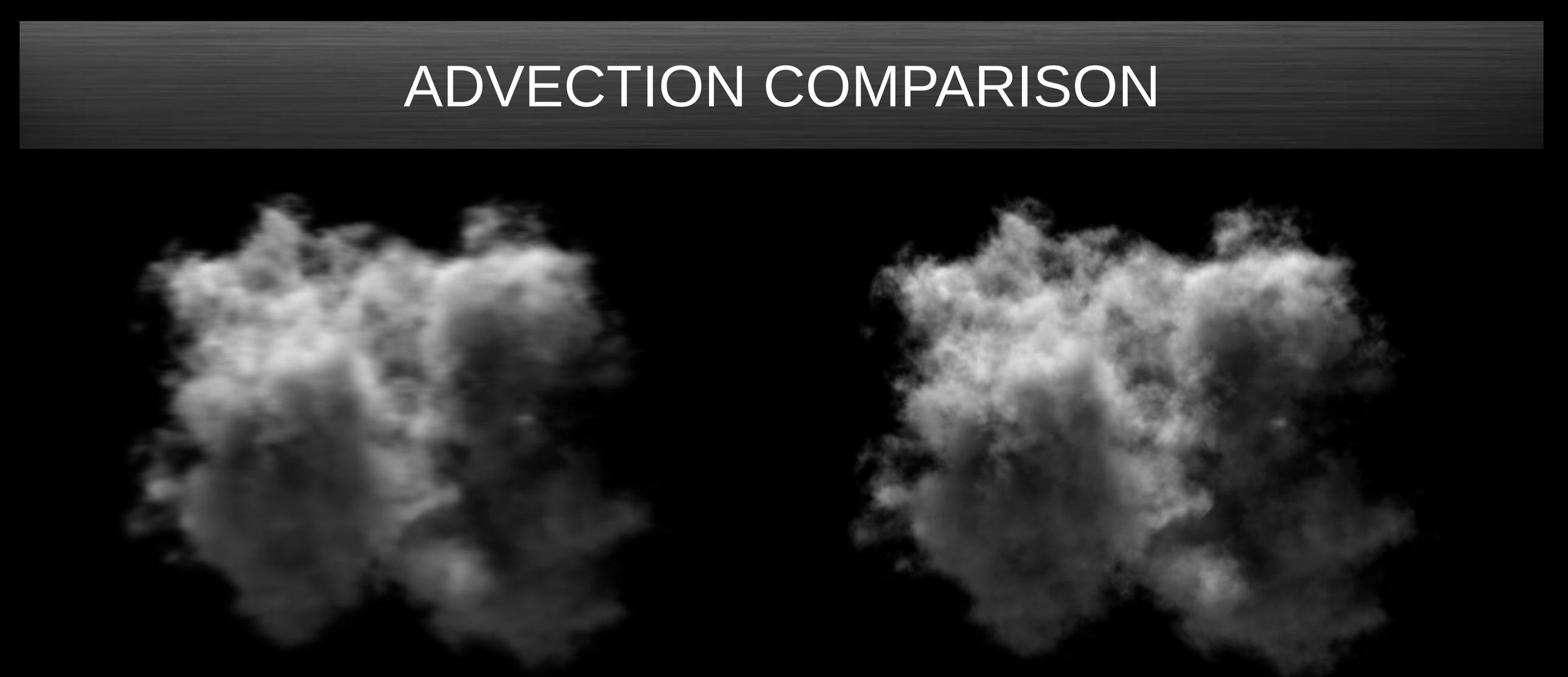
PARTICLE ADVECTION

- Compute Level Set from Cloud density
- Initialize particles based on Level Set
- Interpolate density from grid
- For each frame
  - Advect particles
  - Reseed particles if needed
  - Interpolated density to grid

ADVECTION COMPARISON



Semi-Lagrangian advection

Particle advection

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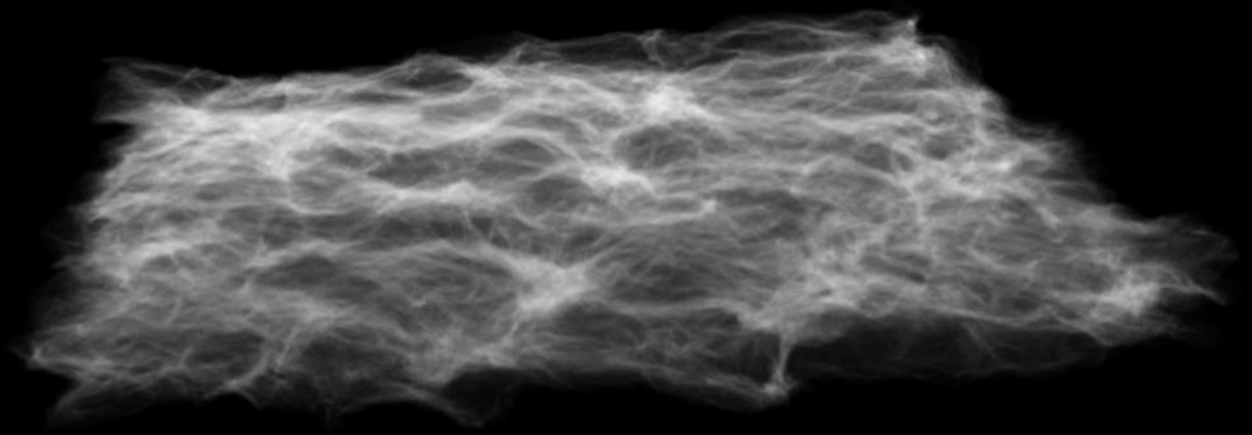
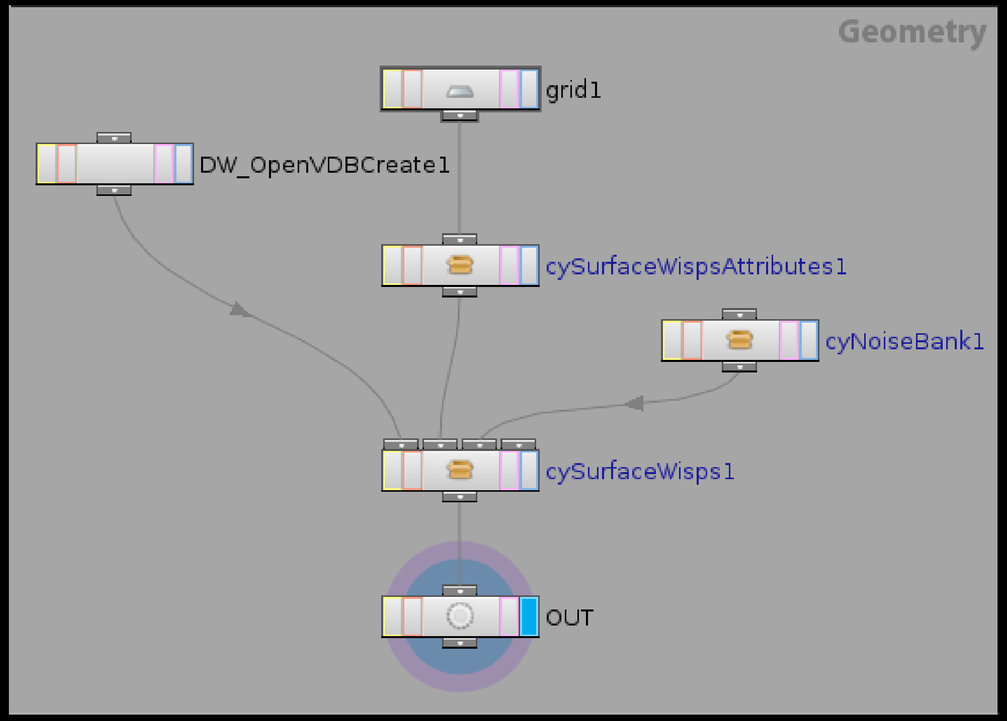
ON THE HORIZON

- Volume modeling
- Storm + OpenVDB
- Improve workflow
- Points, Splines, Surfaces





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- OpenVDB team

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