OpenVDB

Presenters:
Ken Museth, John Lynch,
Jeff Budsberg, Dan Bailey

Schedule

- **9:00am**
  - Introduction to OpenVDB, Ken Museth (DWA)
- **9:20am**
  - OpenVDB in Houdini, John Lynch (SideFX)
- **9:40am**
  - Adoption at DreamWorks Animation, Jeff Budsberg (DWA)
- **10:10am**
  - Advanced applications of OpenVDB in production, Dan Bailey (DNeg)

Course Material

- Main site: http://www.openvdb.org
  - Course slides from 2015 & 2013
  - Coding cookbook and FAQ
  - Example files: vdb & Houdini hip
  - Google group: “OpenVDB Forum”
- Technical paper on VDB: http://ken.museth.org

Dry Facts

- History of development
  - Starting in 2007 (DB-Grid/DB+Grid/VDB)
  - Open source in 2012 (v0.9)
- OpenVDB core developers
  - K. Museth*, P. Cucka, M. Aldén* and D. Hill
- Source code
  - Tar-balls: http://www.openvdb.org
  - GitHub: https://github.com/dreamworksanimation/openvdb_dev
- License
  - Mozilla Public License version 2 and CLA

Commercial Adoption

DreamWorks Animation SKG

OpenVDB

PIXAR's RenderMan®

MODO®

REALFLOW

Guerilla Render

arnold

SOLIDANGLE

Houdini

3D ANIMATION TOOLS

3delight

CHAOSGROUP

v-ray

clarisse iFX

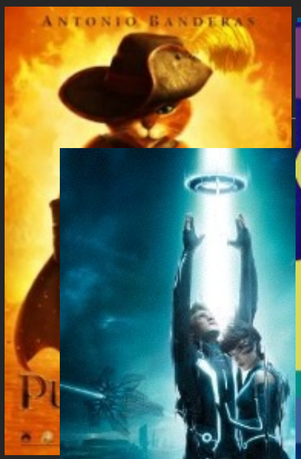
STOKE MX

MAXWELL RENDER

octanerender

Autodesk® Maya

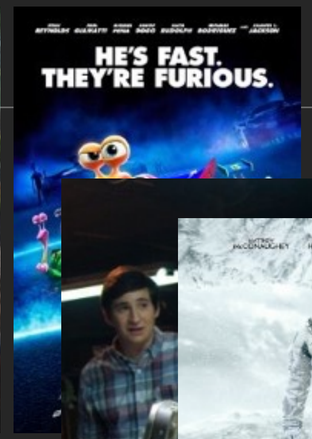
VES Reference Platform

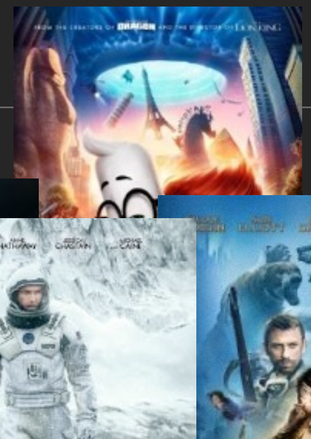

ANTONIO BANDERAS

TRON
LEGACY


FROM THE CREATORS OF UP
DISNEY PIXAR
INSIDE OUT
MEET THE LITTLE VOICES INSIDE YOUR HEAD.
JUNE 19

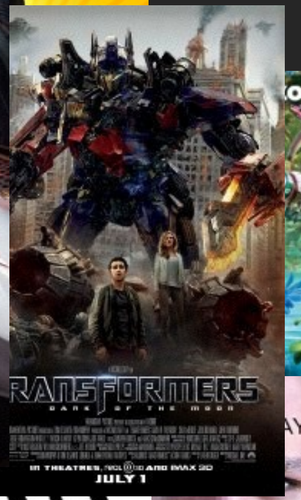

THE
GOD
OF
THUNDER
THOR
MAY 6


HE'S FAST.
THEY'RE FURIOUS.



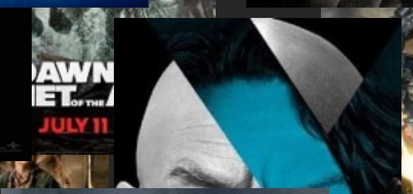

JACK BLACK

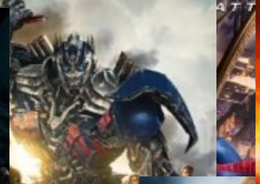
SPEED RACER
GO! MAY 9TH


TRANSFORMERS
DARK OF THE MOON
IN THEATRES, 3D AND IMAX 3D
JULY 1

INTERSTELLAR
IN THEATRES AND IMAX
NOVEMBER 7


THE GOLDEN COMPASS
12·7·07





BRENDAN FRASER


CHANNING TATUM
MILA KUNIS
JUPITER
ASCENDING
FROM THE CREATORS OF THE MATRIX TRILOGY
FEBRUARY 6, 2015


WALT DISNEY PICTURES
PIRATES OF THE CARIBBEAN
AT WORLD'S END
MAY 25

PRESIDENTS' DAY

GODZILLA


GUARDIANS
OF THE GALAXY

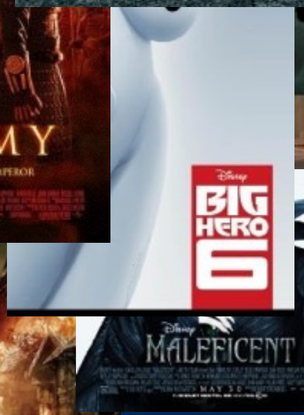

JUPITER
ASCENDING
JULY 18

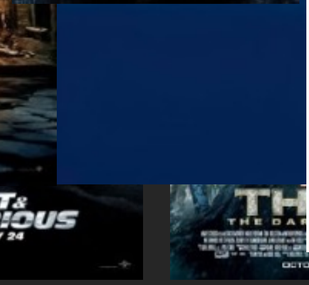

G.I.JOE
RETALIATION
MARCH 28

THE
MUMMY
TOMB OF THE DRAGON EMPEROR


THE
HOBBIT
COMIC-CON 2014

FAST & FURIOUS 6
MAY 24


Disney
BIG HERO 6


Disney
MALEFICENT


WORLDS COLLIDE
DREAMWORKS
HOME
MARCH 27

G.I.JOE
THE RISE OF COBRA
AUGUST 7

Library Versioning

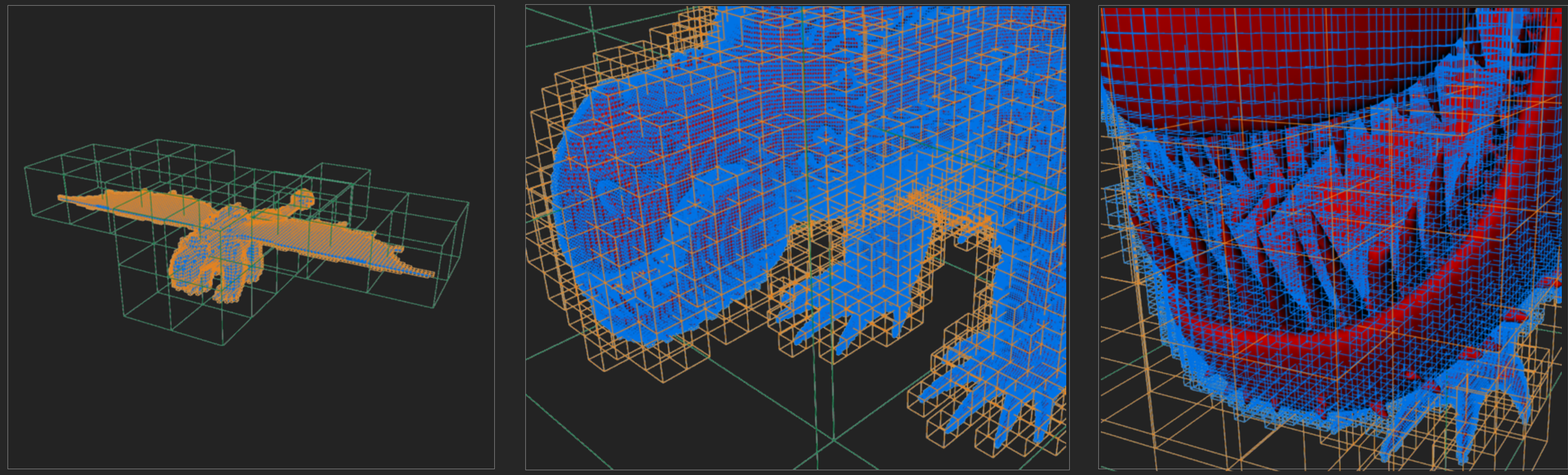
major.minor.patch

- Patch:
  - No change to API, file format or ABI of Grid or its member classes
- Minor:
  - Change to API but not Grid ABI; backward-compatible file format
- Major:
  - Change to ABI of Grid or non-backward-compatible file format
- Library is namespaced on the complete version number
  - No release guarantees complete ABI compatibility!
  - Guaranteed Grid and file compatibility with fixed Major

Terminology

- Voxel [= Volume + Pixel]
  - Smallest addressable unit of index space
  - Resides at the leaf node level
- Tile
  - Larger constant domain of index space
  - Resides at the upper (non-leaf) tree levels
- Active state
  - All values (voxels and tiles) have a binary state
  - Interpretation of state is application-defined

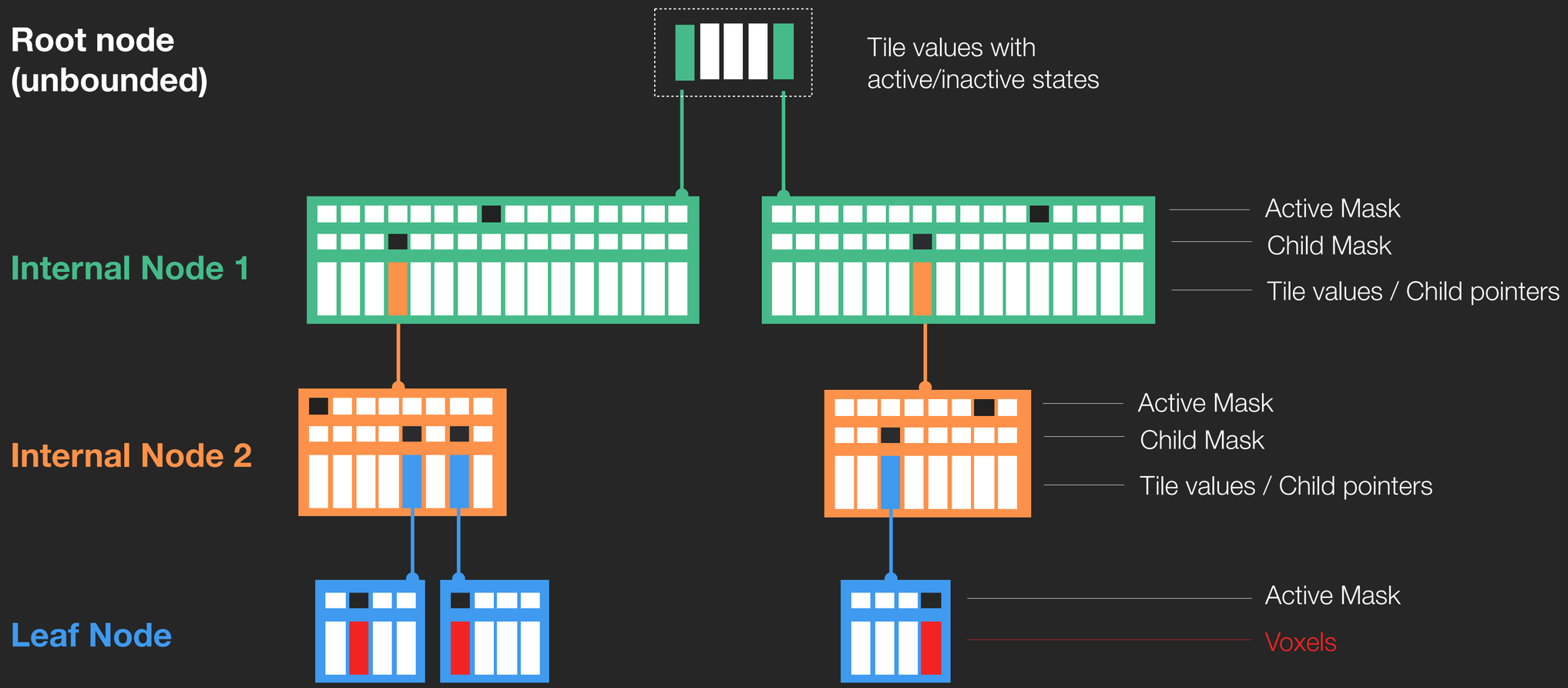
Properties of VDB



7897 x 1504 x 5774

- Unbounded
- Sparse
- Fast access
- General

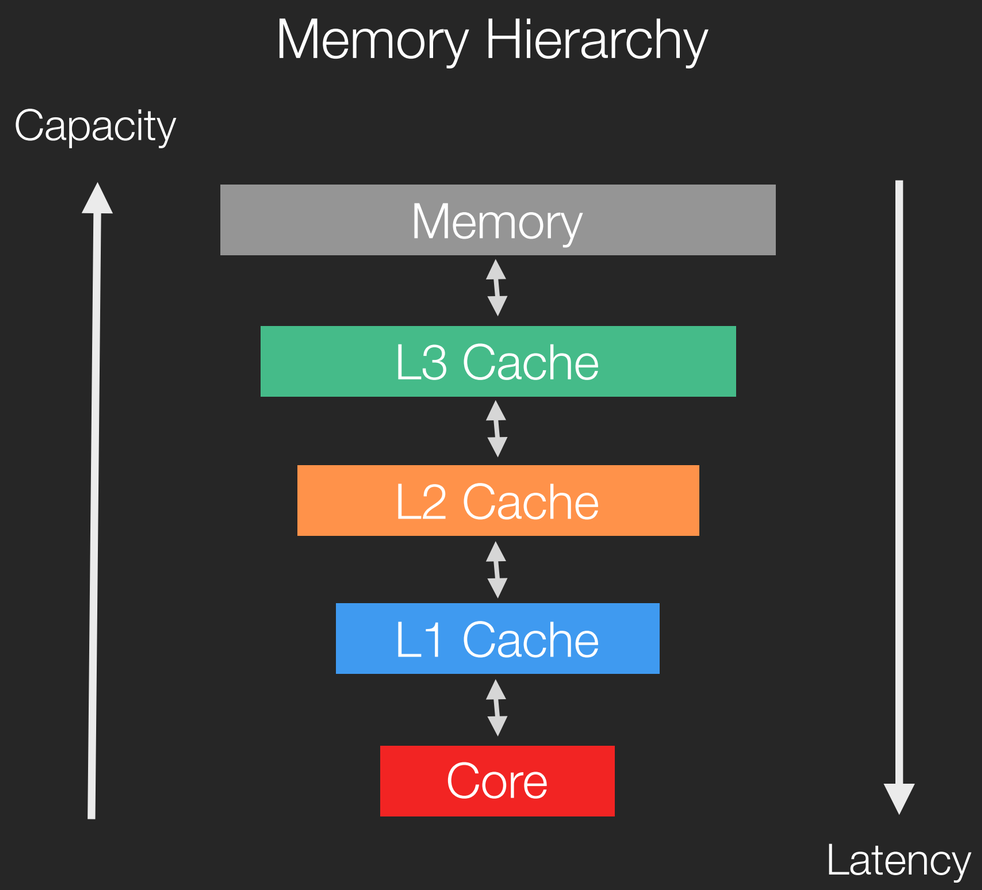
Technical Features

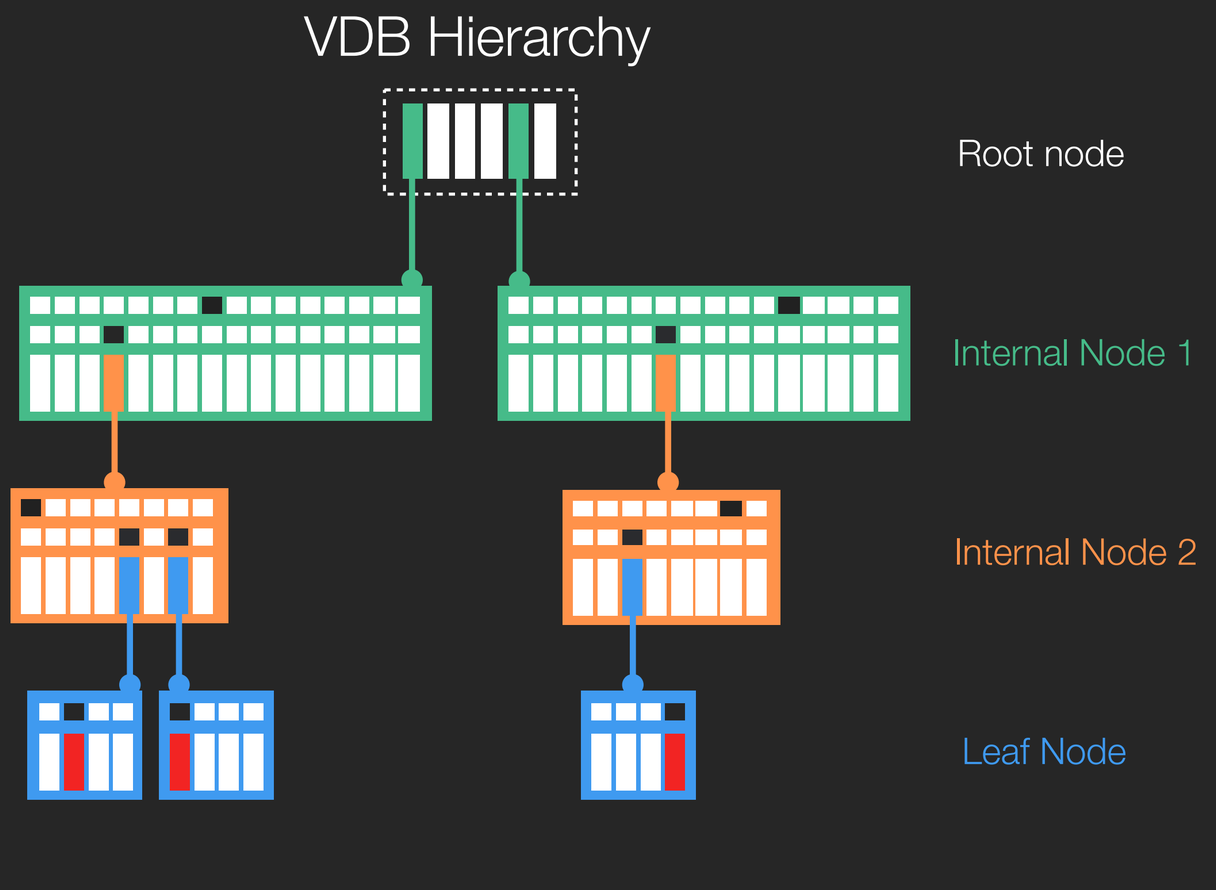


- Unique variant of B+Tree
- Inverted tree traversal
- Bit-mask techniques
- Hierarchical acceleration

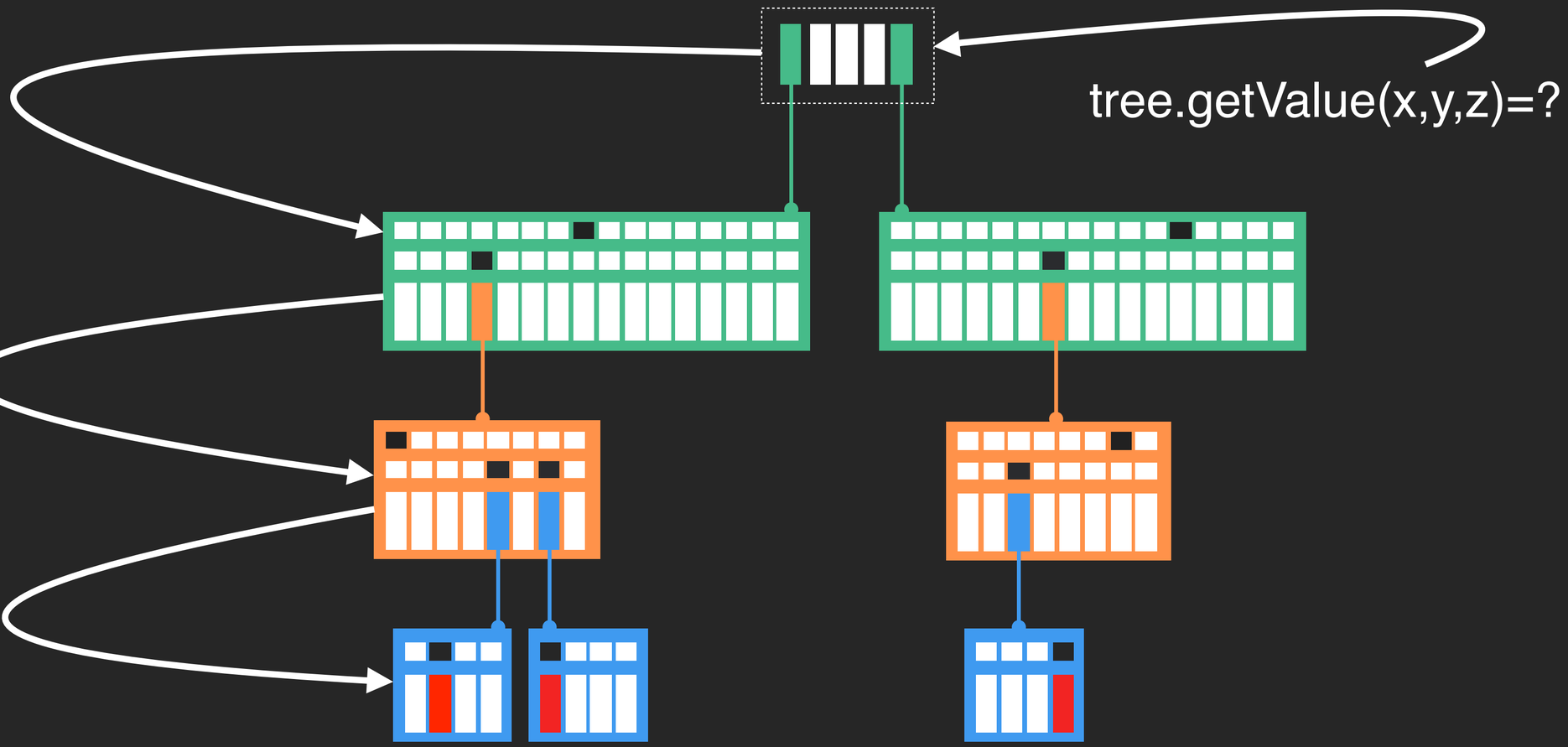
[K. Museth, SIGGRAPH / ACM TOG, 2013]

CPU Analogy

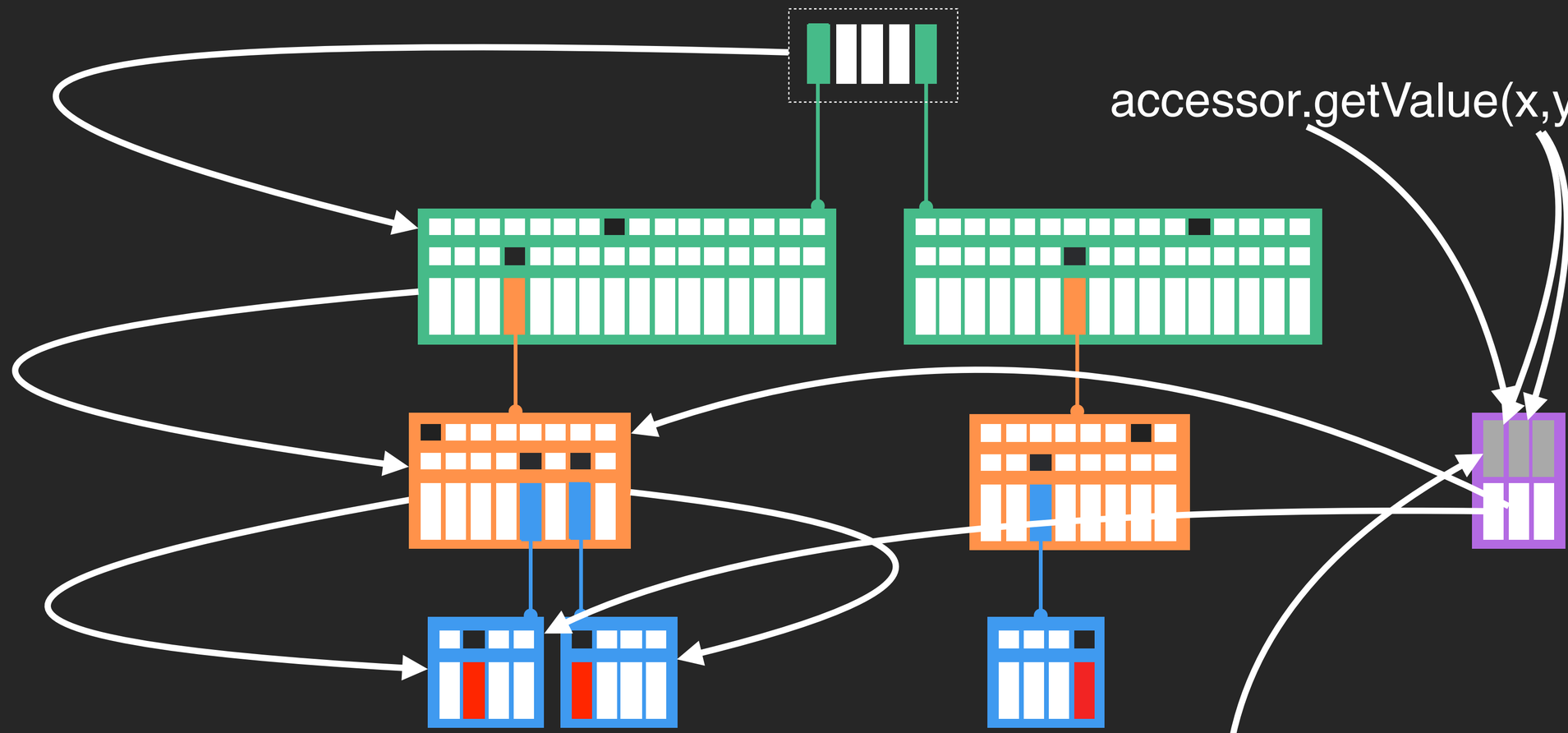

Memory Hierarchy
Capacity
Memory
L3 Cache
L2 Cache
L1 Cache
Core
Latency


VDB Hierarchy
Root node
Internal Node 1
Internal Node 2
Leaf Node

Random Access: Top-Down

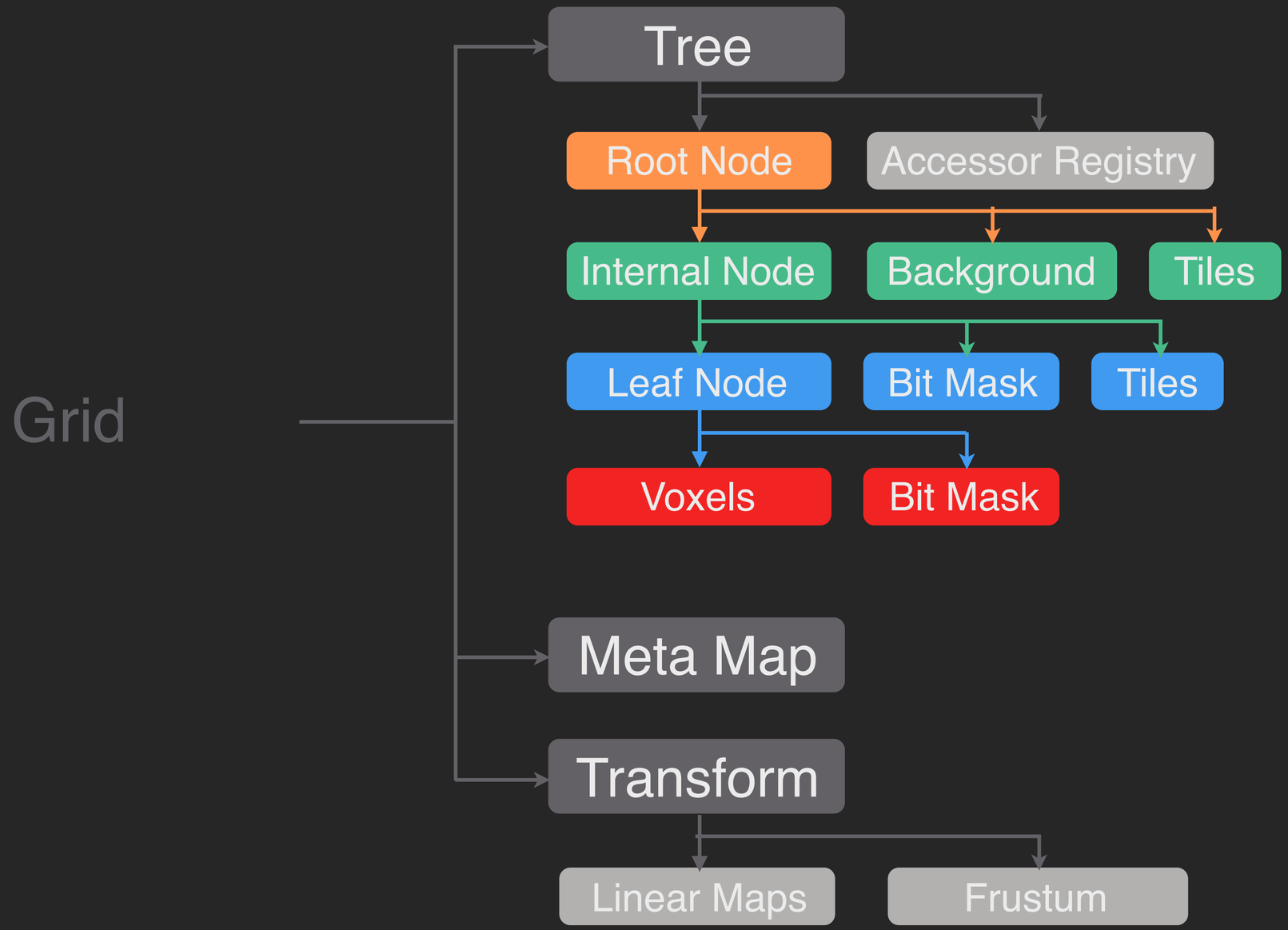


Random Access: Bottom-Up




```
int cacheKey[3] = {x & ~((1 << sLog2X) - 1),
                   y & ~((1 << sLog2Y) - 1),
                   z & ~((1 << sLog2Z) - 1)}
```

Grid/Tree Class Structure



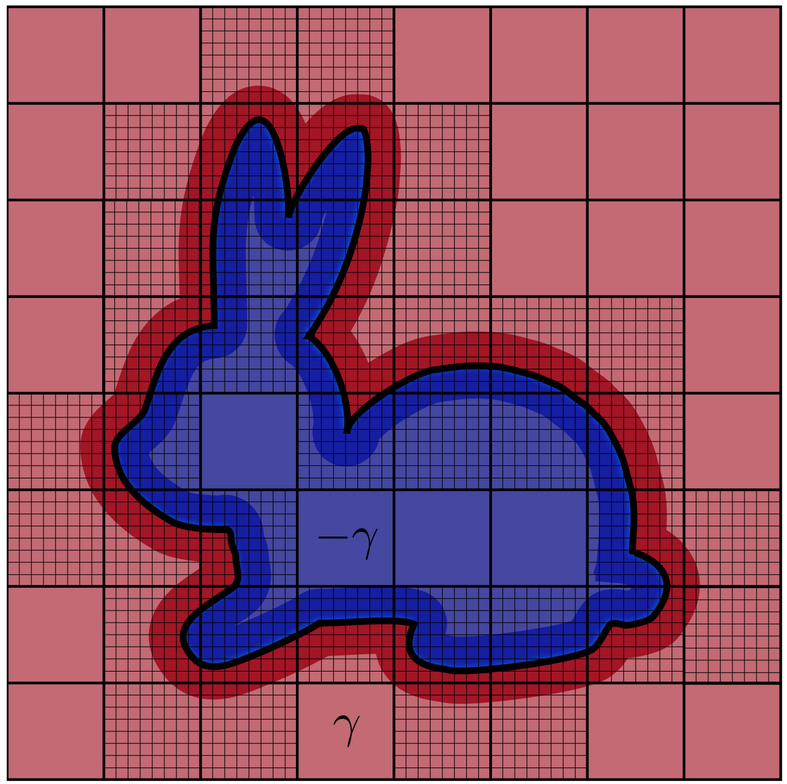
Changes since 2013

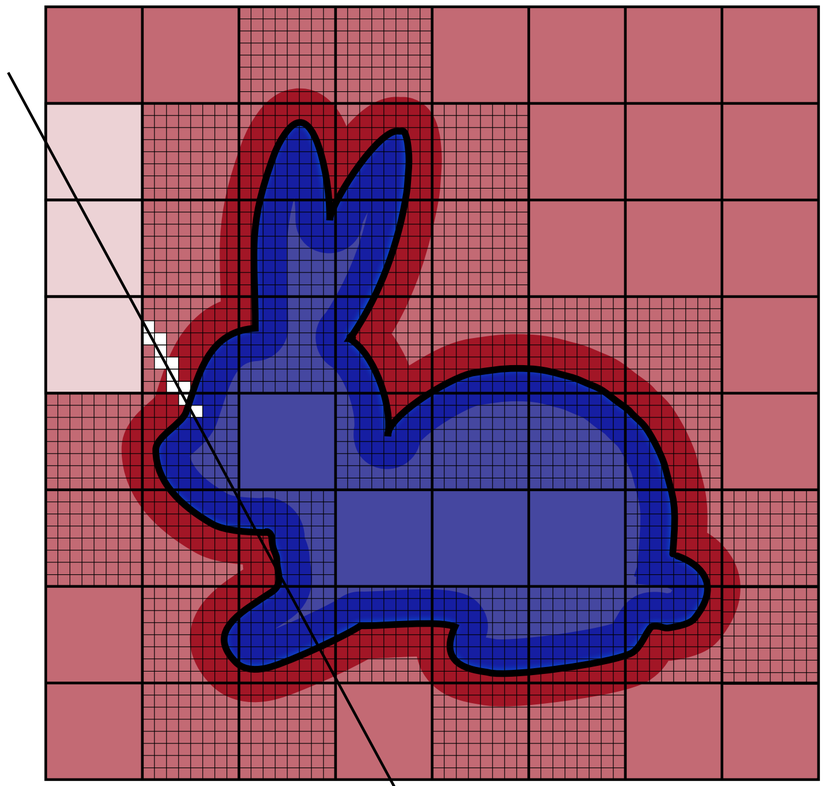
Version 3.1.0 - In development

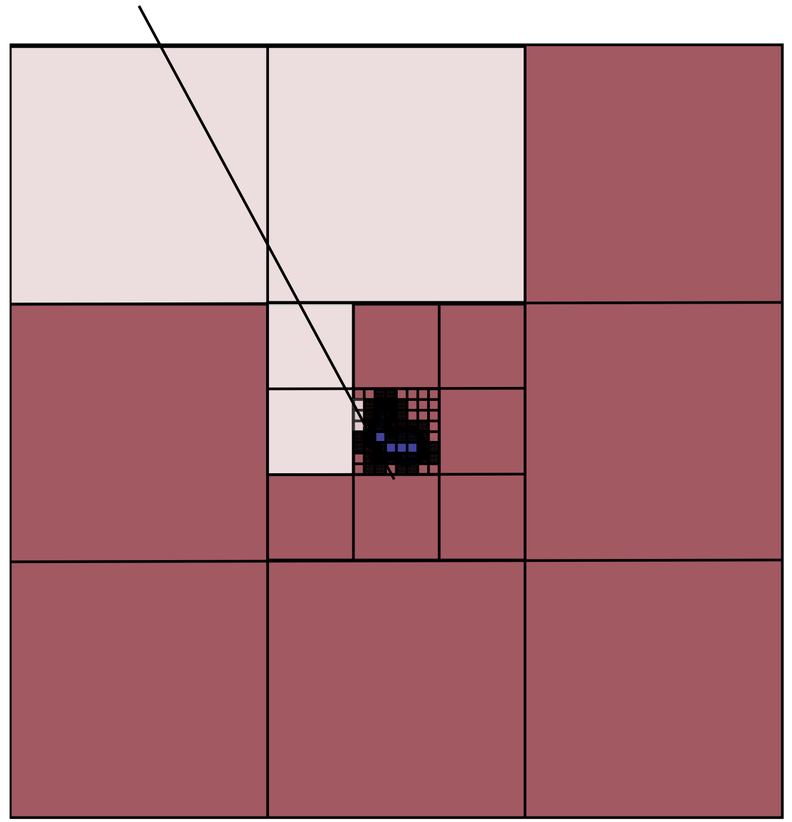
New features:
- Added tools::DensityAdvection for sparse advection of non-level-set volumes.
- Added tools::extractEnclosedRegion to detect topologically enclosed (watertight) exterior regions (cavities) that can arise as the result of a CSG union operation between different level set shapes where at least one of the shapes has a concavity that is capped.
- Added a preconditioned conjugate gradient solver.
- Added a Poisson solver for incompressible fluids that operates on a given domain. Often procedural animation of objects (e.g. characters) interacting with liquid will result in boundary conditions that describe multiple disjoint regions: regions of free surface flow and regions of of trapped fluid. It is this second type of region for which there may be no consistent pressure (e.g. a shrinking watertight region filled with incompressible liquid). The unit test TestPoissonSolver::testSolveWithSegmentDomain demonstrates how to use tools::extractEnclosedRegion in conjuction with the Poisson solver.
- Added util::PagedArray, a thread-safe, dynamic linear array data structure with fast O(1) value access (both random and sequential).
- Added LeafNode::Buffer::data(), which provides direct access to a leaf node's voxel value array, avoiding out-of-core overhead.
- Added tools::Sampler, which provides a unified API for both staggered and non-staggered interpolation of various orders.
- Added equality and inequality operators to Metadata and MetaMap.

A Few Highlights …

- Accelerated ray-marching (HDDA)

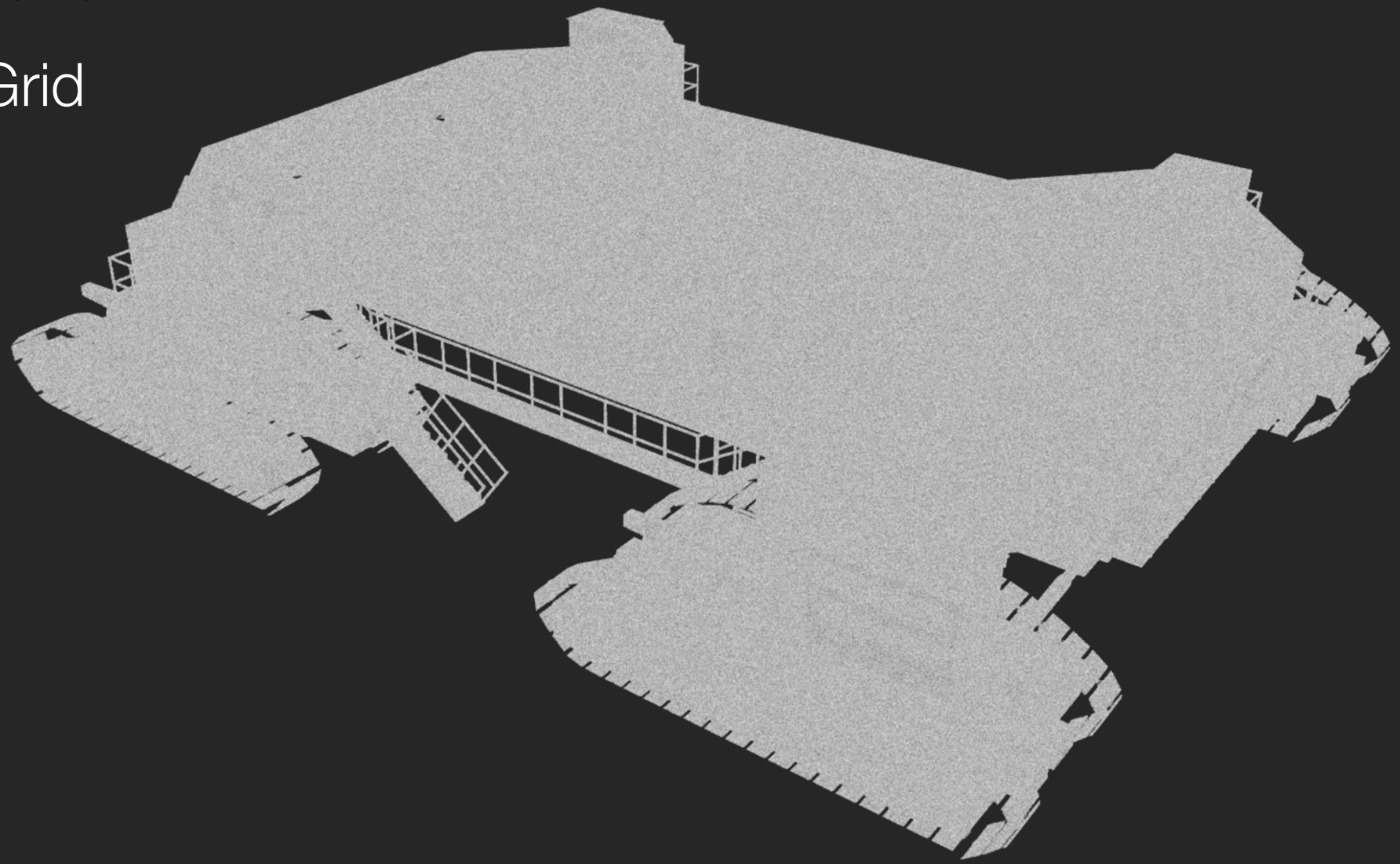






A Few Highlights …

- PointPartitioner
- PointIndexGrid
- PointDataGrid



A Few Highlights …

- Delayed loading (out-of-core processing)
- Blosc LZ4 multi-threaded file compression
- Python scripting support
- Poisson solver ($\nabla^2 \mathbf{x} = \mathbf{b}$), segment trapped liquids
- Density and non-level-set advection
- Level set morphing, measures, clipping, and sphere packing
- Diagnostics tools for level sets, Fog volumes, etc
- Maya nodes (to/from poly, read/write, filter, vis, convert, transform)
- Numerous optimizations, eg Grid copy and topology operations

Houdini SOP Nodes

Advect Density, Advect Level Set, Advect Points, Analysis, Clip, Combine, Convert, Create, Diagnostics, Fill, Filter, Filter Level Set, Fracture, From Particles, From Polygons, Metadata, Morph Level Set, Noise, Occlusion Mask, Platonic, Prune, Rasterize Points, Ray, Read, Rebuild Level Set, Resample, Sample Points, Scatter, Sort Points, To Polygons, To Spheres, Transform, Vector Merge, Vector Split, Visualize, Write

Looking further ahead…

- MultiResGrid: MipMaps for VDB
- Liquid particle decimation
- Improved liquid particle surfacing
- Improved adaptive mesh extraction
- More multi-threading of grid methods and tools
- More focus on fluid related tools
- More cloud modeling tools
- Continue work on particle storage and processing
- Improved adaptivity of tree structure
- C++11 & cleanup of API
- Vectorization: SSE/AVX

We’re hiring!

Ken.Museth@DreamWorks.com