RAYTRACING SCIENTIFIC DATA IN NVIDIA® OPTIX™ WITH GVDB SPARSE VOLUMES

Rama Karl Hoetzlein, April 6th 2016
CONVERGENCE

Video Games

Motion Pictures
CONVERGENCE

Video Games

Motion Pictures

Mathematics

Physical Sciences

SpaceX

GVDB

Data Visualization

ProVis / CAD
NVIDIA OptiX

NVIDIA OptiX
OUTLINE

- Science - SpaceX
- Volume Visualization
- Motion Pictures - OpenVDB
- Provis Graphics - NVIDIA OptiX
- GVDB Sparse Volumes
- Results
SpaceX
Wavelet Simulation Source Data

SpaceX Dragon Capsule Re-entry

3D Sparse Volume data:
3864 x 944 x 464

Adam Lichtl, Stephen Jones, GPU Technology Conference 2015
SPACEX

Data Preparation

Wavelet Cloud

Data Visualization
A Numerical Study of High-Pressure Oxygen/Methane Mixing and Combustion of a Shear Coaxial Injector, Nan Zong & Vigor Yang, AIAA 2005

NVIDIA INDEX      HPC Visualization Using NVIDIA Index
Tom-Michael Thamm, Christopher Lux, Marc Nienhaus

See show floor!
VOLUME VISUALIZATION

Dense Volumes

16 x 16 =

256 data values
VOLUME VISUALIZATION

Dense Volumes

16 x 16 =

256 data values
VOLUME VISUALIZATION

Dense Volumes
VOLUME VISUALIZATION

Dense Volumes

- 8 empty steps
- 5 sample steps
VOLUME VISUALIZATION

Sparse Volumes

- 52 data values
  (instead of 256!)
- 2 DDA skip steps
- 5 sample steps
VOLUME VISUALIZATION

Octree Topology
- Many levels
- Every level divided in half

Tilemap Topology
- Only two levels
- Map has uniform divisions
SPACEX
Data Preparation with OpenVDB

Wavelet Cloud
Ideal for GPU Simulation.
Difficult to directly visualize.

OpenVDB Grid
Sparse, Spatial Grid Hierarchy.
Efficient storage and visualization.
MOTION PICTURES: OPENVDB
MOTION PICTURES: OPENVDB
Sparse Hierarchy of Grids

Novel topology for very large volumes.
Multi-core CPU Design

VDB: High-Resolution Sparse Volumes with Dynamic Topology
OPENVDB
VDB Topology

Many levels
Each level is a grid
Each level has its own resolution
e.g. top = 4x4
     mid = 3x3
     brick = 4x4

Key features:
Can store very large volumes with only a few levels.
Efficient to traverse, since every level is a grid.
OPENVDB VS AMR
Sparse Hierarchy of Voxel Grids

OpenVDB:
1) Children are strictly contained
2) Spatial extent is a voxel of parent
3) All siblings have same resolution

Adaptive Mesh Refinement (AMR):
1) Children are strictly contained
2) Spatial extent is free in parent
3) Siblings can have different resolution
SUMMARY OF GOALS

1. Load and Visualize Sparse Grids
2. Using the VDB Data Structure
3. ..with.. Efficient Rendering on GPU
4. ..and.. *High quality Raytracing*
NVIDIA DesignWorks™ - Advanced technologies for design applications

https://developer.nvidia.com/designworks
NVIDIA DesignWorks™ - Advanced technologies for design applications

https://developer.nvidia.com/designworks
OptiX: A General Purpose Ray Tracing Engine
OptiX SDK

• Available for free: Windows, Linux, Mac
• http://developer.nvidia.com
NVIDIA GVDB SPARSE VOLUMES

Data Visualization

GVDB
Efficient GPU Structures, Raytracing and Compute

NVIDIA OptiX
High Quality Raytracing

OpenVDB
CPU Format and Layout
NVIDIA GVDB SPARSE VOLUMES

What is GVDB?

VDB Sparse Voxel Structures entirely on GPU
Efficient Direct Raytracing
Compatible with OpenVDB files and layout
Integrated with NVIDIA OptiX
Compute Operations on Sparse Volumes
NVIDIA GVDB SPARSE VOLUMES

VDB Topology

Additional features:
- Run-time tree configuration
- Dynamic topology
- Efficient construction

Same topology as OpenVDB
# NVIDIA GVDB SPARSE VOLUMES

## VDB Topology

<table>
<thead>
<tr>
<th>CPU</th>
<th>GPU</th>
</tr>
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<tbody>
<tr>
<td><img src="image1.png" alt="VDB Topology" /></td>
<td><img src="image2.png" alt="VDB Topology" /></td>
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## Value Atlas

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**Brick**

- ![Brick](image3.png)

**Voxels**

- ![Voxels](image4.png)
RESULTS
624 x 304 x 304 (133 MB/frame)

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RESULTS

Scalability Testing

Fluid simulations from Smooth Particle Hydrodynamics

1,000,000 Particle simulation on GPU using Fluids v.3, http://fluids3.com

Generated volumes at multiple resolutions by resampling velocity field

Low-res: 512 x 180 x 256, 50 MB/frame, 60 GB total
Med-res: 1024 x 360 x 512, 338 MB/frame, 408 GB total
High-res: 2048 x 720 x 1024, 2.4 GB/frame, 3 TB total
RESULTS

Source Data:
1 million Particles
Simulated at 20 fps
RESULTS

Low Resolution
512 x 180 x 256

- # of Leaves: 12,131
- File size: 50 MB/frame
- GPU Resampling: 16 seconds/frame
- Load Atlas: 450 msec/frame
- Raytracing: 27 msec/frame, 38 fps

High Resolution
2048 x 720 x 1024

- # of Leaves: 616,444
- File size: 2400 MB/frame
- GPU Resampling: 804 seconds/frame
- Load Atlas: 5420 msec/frame
- Raytracing: 64 msec/frame, 15 fps
RESULTS

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48x more data
2x time

38 fps
INTERACTIVE RENDERING
1 ray / pixel

Time (ms)

35 fps

Empty Skipping: 6.3
Volume Render: 28.2
Isoval Render: 26.4

Low Res 512

Medium Res 1024

High Res 1536

Highest Res 2048

26 fps

19 fps

16 fps

28.2 26.4

54.3 58.1

67.4 68.2

38.0 43.2

9.6

7.4

9.8

54.3

9.6

67.4

35 fps

26 fps

19 fps

16 fps
NVIDIA GVDB SPARSE VOLUMES

Data Example: Simulate, Process and Raytrace of 1200 frames

Simulate
- SPH Simulation
  - On GPU /w Fluids v.3

Processing
- Resample Points to 1024³ Grid
  - On GPU Sparse resample

Render
- Write VBX
- Read VBX Raytrace

Total:
- 1 min
- 6 hours
- 1 hours
- 9 min 46 min

Processing:
- 4 seconds/frame

Rendering:
- 1200 frames in <1 hour with shadows and scattering
- 192 rays / pixel

Disk total: 530 GB
User Application

OptiX API

Launch!

Acceleration Structures

Ray Shade Program

Mesh Hit Program

JIT Compiler

Scheduler

GPU
Poly-to-Voxel Scattering
Poly-to-Poly Scattering
Interested in GVDB?
Let us know!

http://developer.nvidia.com/gvdb

Rama Karl Hoetzlein
NVIDIA
THANKS! TO..

SpaceX
Stephen Jones
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Steven Parker

NVIDIA IndeX
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Tom-Michael Thamm

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THANK YOU

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