Cinematic Scientific Visualization in Houdini

Kalina Borkiewicz + AJ Christensen
Advanced Visualization Lab
National Center for Supercomputing Applications
University of Illinois at Urbana-Champaign
Vocabulary

Renaissance Team  *n.*

1. A cross-disciplinary group of experts in science, technology, and art, who work together to build extremely effective science outreach projects.
Vocabulary

Cinematic Scientific Visualization  \( n. \)

1. Production-quality, data-driven imagery created with movie-making tools with good composition, camera direction, and artistic aesthetics suitable for distribution in immersive giant screen theaters.

Scientific Visualization  \( n. \)

1. Imagery created using data with spatial 3D coordinates, often calculated on large computing clusters.

Scientific Illustration  \( n. \)

1. Imagery created based on expert input but using predominantly artistic tools.

Information Visualization  \( n. \)

1. Imagery created using relational data which often has no direct mapping to spatial coordinates.
Cinematic Sci Vis
Demo Reel Video

https://youtu.be/T_0ICxROM0Q
Recent Examples
Double Coronal Mass Ejection

**SIMULATION STATS**

- **DATA SIZE**: 2.8 TB
- **TIME STEPS**: 1794
- **RESOLUTION**: $577R \times 384\theta \times 432\phi$
- **SPATIAL SCALE**: 1x - 6.25x solar radius
- **TIME SCALE**: 100 minutes

**SCIENTIST**
Yuhong Fan

**INSTITUTION**
Nat. Center for Atmos. Research
Yellowstone, NWSC/NCAR and Discover, NASA Center for Climate Simulation

**SUPERCOMPUTER**
BIG DATA

**DOUBLE CORONAL MASS EJECTION**
BIG DATA

El Reno Tornado - May 24, 2011

SIMULATION STATS

| DATA SIZE | 160 TB |
| TIME STEPS | 4895 |
| RESOLUTION | 1500 x 1500 x 380 stretch grid |
| SPATIAL SCALE | 120km x 120km x 120km |
| TIME SCALE | 2 hours |

SCIENTIST | Leigh Orf

INSTITUTION | University of Wisconsin-Madison

SUPERCOMPUTER | Blue Waters, University of Illinois
### BIG DATA

**Photosynthetic Organelle**

#### SIMULATION STATS

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DATA SIZE</strong></td>
<td>60 TB</td>
</tr>
<tr>
<td><strong>TIME STEPS</strong></td>
<td>~100,000</td>
</tr>
<tr>
<td><strong>RESOLUTION</strong></td>
<td>~100,000,000 atoms</td>
</tr>
<tr>
<td><strong>SPATIAL SCALE</strong></td>
<td>1 Angstrom (1e-10 m)</td>
</tr>
<tr>
<td><strong>TIME SCALE</strong></td>
<td>1 femtosecond (1e-15 s)</td>
</tr>
</tbody>
</table>

**SCIENTIST**         | Klaus Schulten                             |
**INSTITUTION**        | University of Illinois at U-C              |
**SUPERCOMPUTER**      | Blue Waters and Titan                      |
Scientific Visualization Tools
The Houdini Paradigm
Demo: Deriving Geometry from Data
Demo: Working with External Assets
Demo: Volume and Geometry Manipulation
Programming in Houdini
Ways to Get Your Data into Houdini

A) Custom C++ Plugins
B) Scripting
C) Ytini
Ways to Get Your Data into Houdini

A) Custom C++ Plugins
B) Scripting
C) Ytini
Custom C++ Plugins

Houdini Development Kit (HDK)

Table Of Contents

Getting Data In and Out of Houdini

Geometry Data

- The .geo and .jgeo format are documented at length in /Houdini/Application/geo.txt which ships with Houdini.
- Binding Command Line Geometry Converters
- Using the GEO.c command line tool to import/export geometry by invoking an external command line program.
- Writing GEO.TXTTranslators
  By registering your own GEO.TXTTranslator class, you can write a converter that plugs directly into Houdini, avoiding any intermediate copies.
- https://code.google.com/p/houdinigetset-translator/
  An open source library to re/write Houdini geometry (both ASCII and binary).
- Complete scenes can be imported and exported through the FBX file format: Importing and Exporting Data using FBX

Image Data

3D Texture Images

Channel Data

Lookup Tables

See Also

- SOHO: Scripted Output of Houdini Objects
- SOHO: Simple Examples
Custom C++ Plugins

Houdini Development Kit (HDK)

- Built directly into Houdini, and works seamlessly just like any other feature, without extra or external steps
- Great if you also need custom artistic controls, beyond just reading the data
  - Resolution
  - Interpolation
  - Edge falloff
  - Isovolumes
  - ...

Custom C++ Plugins

Houdini Development Kit (HDK)

- Built directly into Houdini, and works seamlessly just like any other feature, without extra or external steps
- Great if you also need custom artistic controls, beyond just reading the data
  - Resolution
  - Interpolation
  - Edge falloff
  - Isovolumes
  - ...
- Downsides:
  - More programming-intensive than some other solutions
  - Needs to be updated with every Houdini version
Ways to Get Your Data into Houdini

A) Custom C++ Plugins
B) Scripting
C) Ytini
Scripting

- One-time conversion of data into a Houdini-compatible format
  - Have to re-run if you want to make changes

- You can write an external script, or code in Python directly in Houdini
Scripting

- Write script snippets directly in the parameters
Scripting

- Write script snippets directly in the parameters
- Create your own SOP
Scripting

- Write script snippets directly in the parameters
- Create your own SOP
- Code directly inside Houdini
Example .geo volume file

PGEOMETRY V2
NPoints 1 NPrims 1
NPointGroups 0 NPrimGroups 0
NPointAttrib 0 NVertexAttrib 0 NPrimAttrib 0 NAttrib 0

0 0 0 1

Volume 0 1 0 0 0 1 0 0 0 1 -2 2 2 2 constant 0 0 smoke 0 1

0 1 0 1 0 1 0 1

beginExtra
derendExtra
Example .geo volume file

PGEOMETRY V2 ← Header
NPoints 1 NPrims 1
NPointGroups 0 NPrimGroups 0
NPointAttrib 0 NVertexAttrib 0 NPrimAttrib 0 NAttrib 0

0 0 0 1

Volume 0 1 0 0 0 1 0 0 0 1 -2 2 2 2 constant 0 0 smoke 0 1

0 1 0 1 0 1 0 1

beginExtra
dEndExtra
Example .geo volume file

PGEOMETRY V2
NPoints 1 NPrims 1 ← 1 point that defines the center, 1 primitive that is our data volume
NPointGroups 0 NPrimGroups 0
NPointAttrib 0 NVertexAttrib 0 NPrimAttrib 0 NAttrib 0

0 0 0 1

Volume 0 1 0 0 0 1 0 0 0 1 -2 2 2 2 constant 0 0 smoke 0 1

0 1 0 1 0 1 0 1

beginExtra
endExtra
Example .geo volume file

PGEOMETRY V2
NPoints 1 NPrims 1
NPointGroups 0 NPrimGroups 0
NPointAttrib 0 NVertexAttrib 0 NPrimAttrib 0 NAttrib 0

0 0 0 1

Volume 0 1 0 0 0 1 0 0 0 1 -2 2 2 2 constant 0 0 smoke 0 1

0 1 0 1 0 1 0 1

beginExtra
endExtra
Example .geo volume file

PGEOMETRY V2
NPoints 1 NPrims 1
NPointGroups 0 NPrimGroups 0
NPointAttrib 0 NVertexAttrib 0 NPrimAttrib 0 NAttrib 0

0 0 0 1 ← Center point at (0,0,0) * 1

Volume 0 1 0 0 0 1 0 0 0 1 -2 2 2 2 constant 0 0 smoke 0 1
0 1 0 1 0 1 0 1

beginExtra
endExtra
Example .geo volume file

PGEOMETRY V2
NPoints 1 NPrims 1
NPointGroups 0 NPrimGroups 0
NPointAttrib 0 NVertexAttrib 0 NPrimAttrib 0 NAttrib 0

0 0 0 1

Volume 0 1 0 0 0 1 0 0 0 1 -2 2 2 2 constant 0 0 smoke 0 1

0 1 0 1 0 1 0 1

beginExtra
endExtra
Example .geo volume file

PGEOMETRY V2
NPoints 1 NPrims 1
NPointGroups 0 NPrimGroups 0
NPointAttrib 0 NVertexAttrib 0 NPrimAttrib 0 NAttrib 0

0 0 0 1

Volume 0 1 0 0 0 1 0 0 0 1 -2 2 2 2 constant 0 0 smoke 0 1

beginExtra
endExtra

XYZ Resolution: 2x2x2
Example .geo volume file

PGEOMETRY V2
NPoints 1 NPrims 1
NPointGroups 0 NPrimGroups 0
NPointAttrib 0 NVertexAttrib 0 NPrimAttrib 0 NAttrib 0

0 0 0 1

Volume 0 1 0 0 0 1 0 0 0 1 -2 2 2 2 constant 0 0 smoke 0 1

Transformation matrix = \[
\begin{bmatrix}
1 & 0 & 0 \\
0 & 1 & 0 \\
0 & 0 & 1
\end{bmatrix}
\] = identity matrix, which does nothing (no scaling, translating, rotating)

beginExtra
endExtra
Example .geo volume file

PGEOMETRY V2
NPoints 1 NPrims 1
NPointGroups 0 NPrimGroups 0
NPointAttrib 0 NVertexAttrib 0 NPrimAttrib 0 NAttrib 0

0 0 0 1

Volume 0 1 0 0 0 1 0 0 0 1 -2 2 2 2 constant 0 0 smoke 0 1

0 1 0 1 0 1 0 1 0 1

Other fancy settings include:
- Whether to taper the volume and how much
- What values to set past the border of the volume
- How much lossy compression is allowed
- And more... Described in “GPD.txt” file that comes with Houdini
Example .geo volume file

```
PGEOMETRY V2
NPoints 1 NPrims 1
NPointGroups 0 NPrimGroups 0
NPointAttrib 0 NVertexAttrib 0 NPrimAttrib 0 NAttrib 0

0 0 0 1

Volume 0 1 0 0 0 1 0 0 0 1 -2 2 2 2 constant 0 0 smoke 0 1

0 1 0 1 0 1 0 1 ← The data

beginExtra
endExtra
```
Example .geo volume file

PGEOMETRY V2
NPoints 1 NPrims 1
NPointGroups 0 NPrimGroups 0
NPointAttrib 0 NVertexAttrib 0 NPrimAttrib 0 NAttrib 0

0 0 0 1

Volume 0 1 0 0 0 1 0 0 0 1 -2 2 2 2 constant 0 0 smoke 0 1

0 1 0 1 0 1 0 1 ← The data. 8 numbers, as defined by the 2*2*2 resolution

beginExtra
endExtra
Example .geo volume file

PGEOMETRY V2
NPoints 1 NPrims 1
NPointGroups 0 NPrimGroups 0
NPointAttrib 0 NVertexAttrib 0 NPrimAttrib 0 NAttrib 0

0 0 0 1

Volume 0 1 0 0 0 1 0 0 0 1 -2 2 2 2 constant 0 0 smoke 0 1

0 1 0 1 0 1 0 1

beginExtra ← End / extras
endExtra
Let’s Play with Real Data: Hands-on Demo
Ways to Get Your Data in Houdini

A) Custom C++ Plugins
B) Scripting
C) Ytini
>>> import yt
>>> ds = yt.load('/home/kalina/Downloads/sedov_hdf5_chk_0011')
yt : [INFO ] 2017-05-09 15:54:35,873 Particle file found: sedov_hdf5_chk_0011
>>> ds.print_stats()
<table>
<thead>
<tr>
<th>level</th>
<th># grids</th>
<th># cells</th>
<th># cells^3</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>512</td>
<td>8</td>
</tr>
<tr>
<td>1</td>
<td>8</td>
<td>4096</td>
<td>16</td>
</tr>
<tr>
<td>2</td>
<td>64</td>
<td>32768</td>
<td>32</td>
</tr>
<tr>
<td>3</td>
<td>256</td>
<td>131072</td>
<td>51</td>
</tr>
<tr>
<td></td>
<td>329</td>
<td>168448</td>
<td></td>
</tr>
</tbody>
</table>

$t = 1.00075931e-02 = 1.00075931e-02$ $s = 3.17121488e-10$ years

Smallest Cell:
- Width: 5.064e-27 Mpc
- Width: 5.064e-21 pc
- Width: 1.044e-15 AU
- Width: 1.562e-02 cm
1.1 The Data

Begin by downloading the Enzo Tiny Cosmology sample dataset from [here](#). Take note of the directory where this is being saved. Go there, and unzip the folder.

1.2 The Code

Download the `writeAMRVDB.py` Python script from our Bitbucket repository. Take note of the directory where this is being saved.

Open the file in a text editor. Search for the line that starts with `datafilename =`. Write in the path to the data file you downloaded.

Search for the line that starts with `outfilepath =`. Write in the path to the directory where you want to write the output VDB files.
Rendering in Houdini
Demo: Camera, Lighting, and Render Setup