3D Scientific Visualization with Blender

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www.cv.nrao.edu/~bkent/blender
Twitter and Instagram: @VizAstro
Watch the live broadcast of this presentation, courtesy of NCSA, at:

https://youtu.be/8FqGNDvEVWo?t=539
Interesting in learning more?

Book and tutorials available at:

http://www.cv.nrao.edu/~bkent/blender/

https://www.youtube.com/VisualizeAstronomy

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Overview - 3D Scientific Visualization with Blender

- Science domain and data of astronomy
- What and why we need to visualize data
- All about the visualization tool Blender
- Examples
- Intro to using the interface
NRAO Radio Telescopes
Astrophysical Phenomena
What do we do in observational astronomy?

Remote sensing and planetary exploration

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3D Visualization
Remote Sensing

- Imaging from the ground or space of phenomena that we can’t physically reach
- The entire physical Universe is our laboratory
- Spectroscopy
  - Dynamics and kinematics, chemistry
- Imaging
  - Earth looking out, and from orbit looking at planets
- Time-series
  - Asteroid identification, light-curves for planet finding, and pulsar timing for general relativity
Astrophysical Simulations

- N-body simulations
- Smoothed Particle Hydrodynamics
- Numerical Relativity
- Models of...
  - Interacting Binary Stars
  - Active Galactic Nuclei Jets
  - Black Holes
  - Interacting Galaxies

Data from Matt Wood, Texas A&M University-Commerce
Data Rates in Astronomy

- The Atacama Large Millimeter Array (ALMA) in Chile has produced:
  - over 1300 Terabytes of total data in 2014.
  - over 2700 Terabytes of total data in 2016.
- The Very Large Array in New Mexico has the capability of producing a million simultaneous frequency channels.
- Current VLA Sky Survey generates 300 GB of raw data in four hours.
Types of Data in Astronomy
Why do we need to visualize?

In addition to increasing data rates, data are becoming increasingly complex. We have moved from

- the paradigm of studying a single spectral line to thousands of lines
- the paradigm of single galaxy dynamics to millions of galaxies

The parameter space continues to increase - efficient database usage, signal extraction, and visualization methods are required.
High-performance computing

Study from Kent (PASP) 2013

**TABLE 2**

<table>
<thead>
<tr>
<th>Render</th>
<th>Samples $N$</th>
<th>Mean (minutes)</th>
<th>Median (minutes)</th>
<th>SE $\bar{X}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>NVidia CUDA</td>
<td>100</td>
<td>2.82</td>
<td>1.49</td>
<td>0.31</td>
</tr>
<tr>
<td>OpenCL</td>
<td>31</td>
<td>2.17</td>
<td>1.99</td>
<td>0.22</td>
</tr>
<tr>
<td>CPU</td>
<td>154</td>
<td>8.30</td>
<td>6.48</td>
<td>0.47</td>
</tr>
</tbody>
</table>

**Note.**—Rendering time for a Blender session in the Cycles engine at a resolution of $960 \times 540$ pixels with rendering tile sizes of $8 \times 8$ pixels. The benchmark test consisted of 6 camera views and 12 mesh objects totaling 86,391 polygons and 91,452 vertices. The last column describes the standard error of the mean.
Software for 3D graphics

MAYA
LightWave
3DS MAX
HOUDINII
CINEMA 4D
blender
PIXAR's RenderMan

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3D Visualization
Blender
3D Graphics and Visualization
What is Blender?

Blender is:

- 3D graphics software for modeling, animation, and visualization
- Open-source
- A real-time 3D viewer and GUI
- A Python scriptable interface for loading data

http://www.blender.org
Elements of 3D Graphics

We need to consider:

- Models - physical or data containers?
- Textures - 2D, 3D, and projections?
- Lighting - illumination of data - physical or artistic
- Animation - How will the model move and change?
- Camera control - lens selection, angle, image size, and movement and tracking
- Rendering - backend engine choice
- Compositing - layering final output
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3D Visualization
Modeling
Texturing and Mapping
Animation

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3D Visualization
Camera Control and Movement
Rendering Engine

- Blender (included)
- Cycles (included)
- Luxrender ([http://www.luxrender.net/en_GB/index](http://www.luxrender.net/en_GB/index))
Compositing
Rendering and Compositing

a)  
b)  
c)  
d)  
e)  
f)  
Examples
Planetary Models

- High resolution maps from orbit can be combined with atmospheres, backgrounds, and lighting elements for a realistic presentation.

See:  
http://www.blenderguru.com/videos/create-a-realistic-earth/

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3D Visualization
Data Cubes

- Gridded data can come from telescopes or simulations
- Radio telescopes produce grids that cover...
  - Two sky coordinates (X and Y)
  - Frequency (Z - the doppler shifted velocity)
- These cubes can show the dynamics of galaxies, planetary disks, and large scale structure formation of clusters
Data Cubes

- Density maps of the nearby Universe can be created on regularly spaced grids.
- The results of these surveys allow to study not only the density of galaxies in 3D, but also the effects of gravity in the same regions of space...
Data from Saunders et al. 2000 and Schmoldt et al. 1999
N-body Simulations

- Data generated from GADGET-2 (Galaxies and Dark Matter Interacting 2)
  N-body/SPH code:
  - [http://www.mpa-garching.mpg.de/gadget/](http://www.mpa-garching.mpg.de/gadget/)
- 30,000 particles, 1100 snapshots run for 2 billion years
- Blender Python interface used to bring XYZ position data into the vertices of Blender objects
- Objects are “textured” with Halos.
- Each grid square is approximately 33,000 light years
Galaxy Catalogs

Courtois et al. 2009 and the extragalactic distance database
Other Sciences: Biology

http://www.bioblender.org
Other Fields: Geography

408 MHz  NASA SkyView or Montage (Berriman et al.)
Google Spatial Media Module
360 Panoramas (Kent 2017)

Courtois and Tully et al. Extragalactic Distance Database

https://www.youtube.com/watch?v=vW93wkDqz54
AstroBlend

Jill Naiman et al.

Rhys Taylor et al.

Matias Garate et al.
Education and public outreach

Thomas Madura

Benedikt Diemer and Isaac Facio

NRAO NINE Program
PASP Special Issue

Contribute to Volume 2!

A Tour of the Blender Interface
Blender interface

Translation

Rotation

Scaling
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