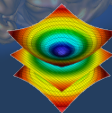


Scalable HPC Visualization and Data Analysis using VisIt



Blue Waters Webinar Series

Wednesday March 15th, 2017

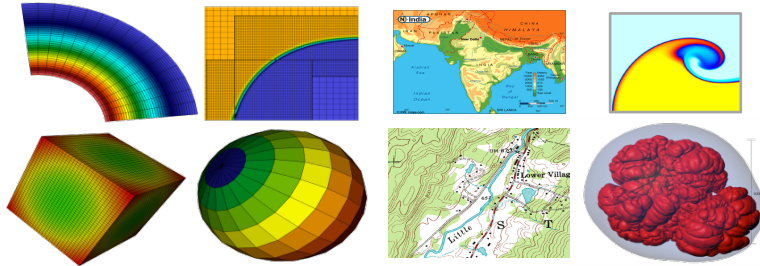
This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344. Lawrence Livermore National Security, LLC

LLNL-PRES-726601

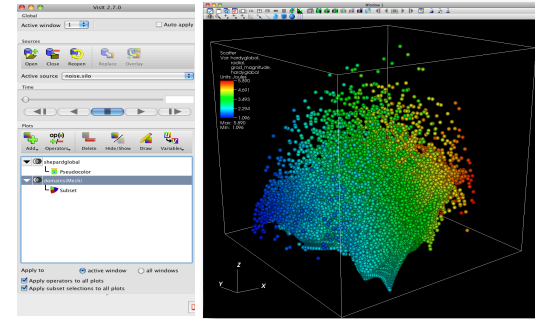


Tutorial Topics

- An introduction to Scientific Visualization using VisIt



Scientific Visualization Concepts



Guided Tour of VisIt

- Hands-on Demonstration: Visualizing a Blood Flow simulation



Tutorial Speakers

Kevin Griffin



Cyrus Harrison



Eric Brugger





Tutorial Resources

- **Tutorial Preparation**

- http://visitusers.org/index.php?title=Tutorial_Preparation

- **Example Datasets**

- http://visitusers.org/index.php?title=Tutorial_Data

- **Aneurysm Simulation Exploration**

- http://visitusers.org/index.php?title=Blood_Flow_Aneurysm_Tutorial

- **Additional Tutorial Materials**

- http://visitusers.org/index.php?title=Visit_Tutorial



Tutorial Outline

- VisIt Project Introduction
- Techniques for visualizing mesh-based simulations
- Guided tour of VisIt
- Visualization of an Aneurysm (Blood Flow) Simulation



Tutorial Data Acknowledgements

Aneurysm Simulation Dataset

Simulated using the LifeV (<http://www.lifev.org/>) finite element solver.

Available thanks to:

- Gilles Fourestey and Jean Favre
Swiss National Supercomputing Centre (<http://www.cscs.ch/>)



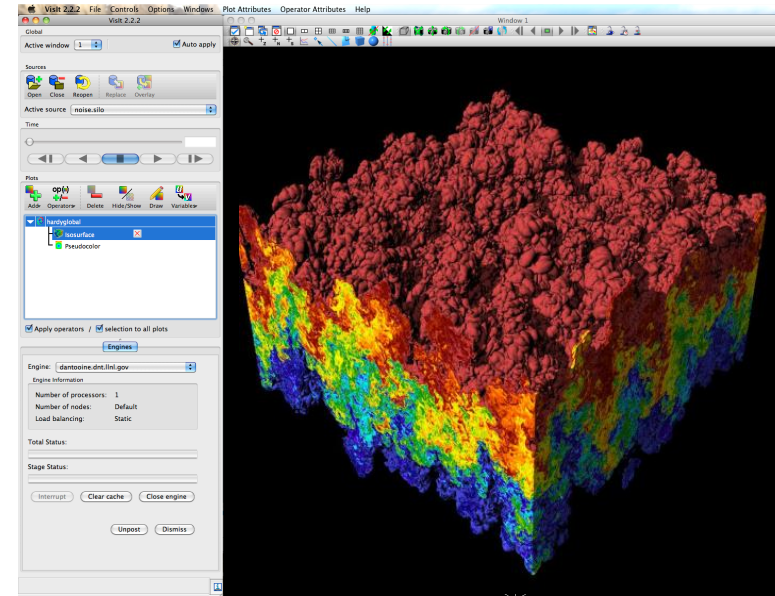
VisIt Project Introduction





VisIt is an open source, turnkey application for data analysis and visualization of mesh-based data.

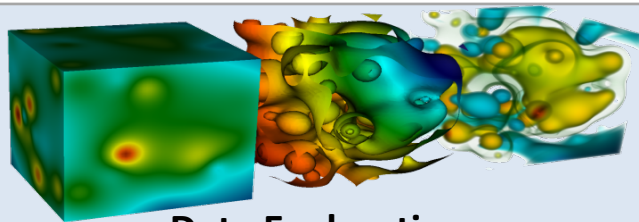
- Production end-user tool supporting scientific and engineering applications.
- Provides an infrastructure for parallel post-processing that scales from desktops to massive HPC clusters.
- Source released under a BSD style license.



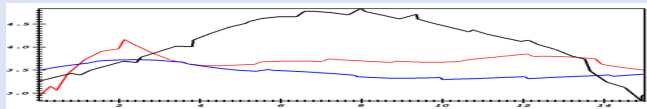
Pseudocolor plot of Density
(27 billion element dataset)



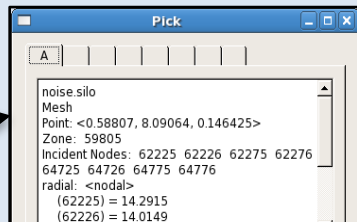
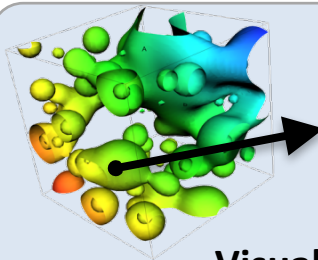
VisIt supports a wide range of use cases.



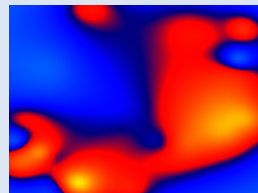
Data Exploration



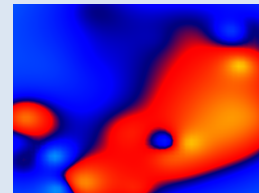
Quantitative Analysis



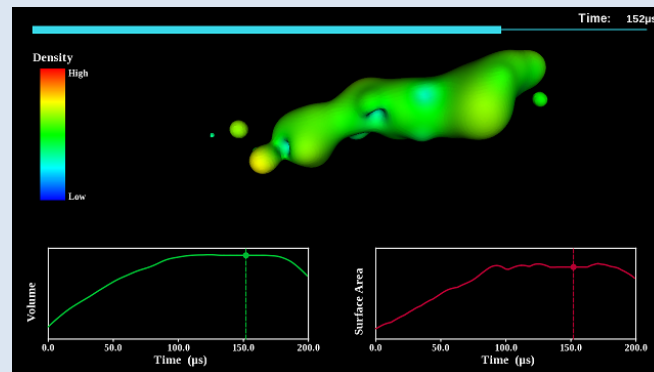
Visual Debugging



||-?



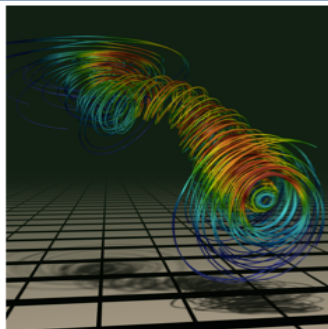
Comparative Analysis



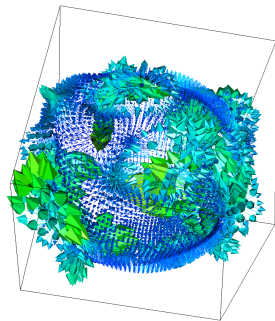
Presentation Graphics



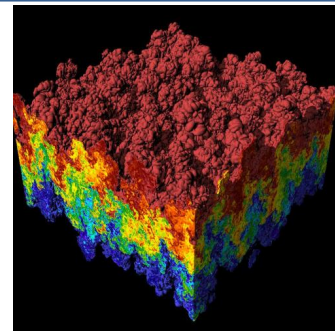
VisIt provides a wide range of plotting features for simulation data across many scientific domains.



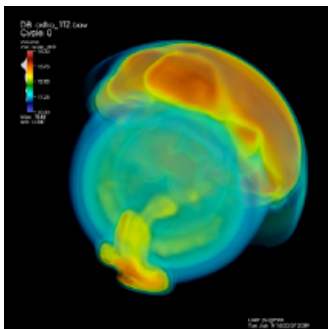
Streamlines / Pathlines



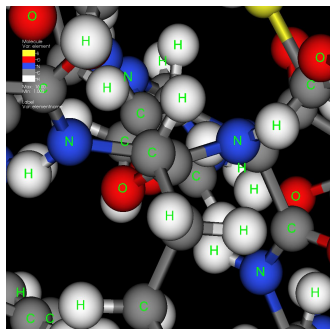
Vector / Tensor Glyphs



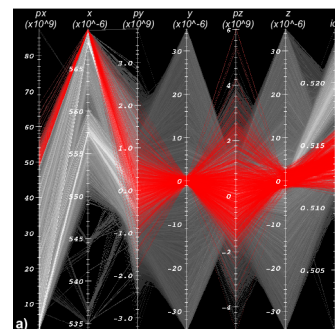
Pseudocolor Rendering



Volume Rendering



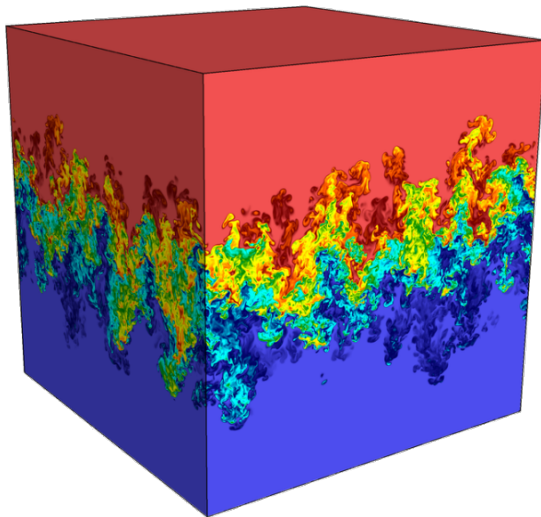
Molecular Visualization



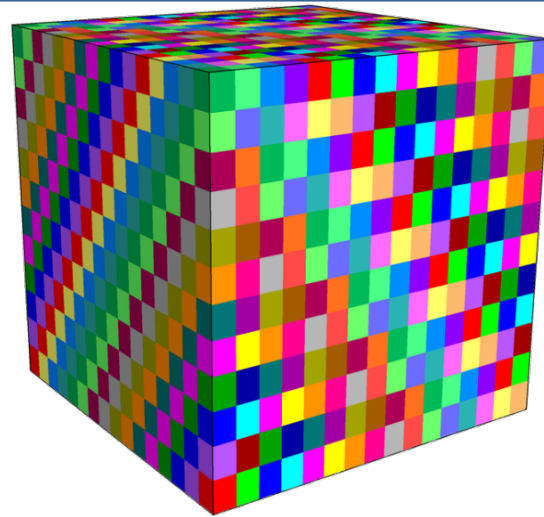
Parallel Coordinates



VisIt uses MPI for distributed-memory parallelism on HPC clusters.



Full Dataset
(27 billion total elements)



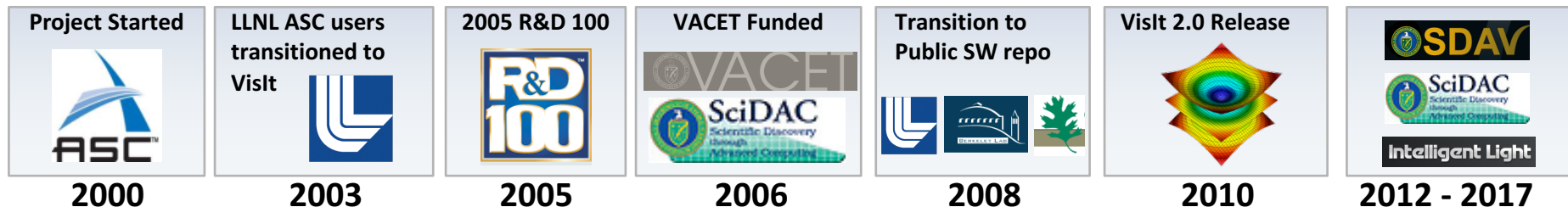
3072 sub-grids
(each 192x129x256 cells)

We are enhancing VisIt's pipeline infrastructure to support threaded processing and many-core architectures.



VisIt is a vibrant project with many participants.

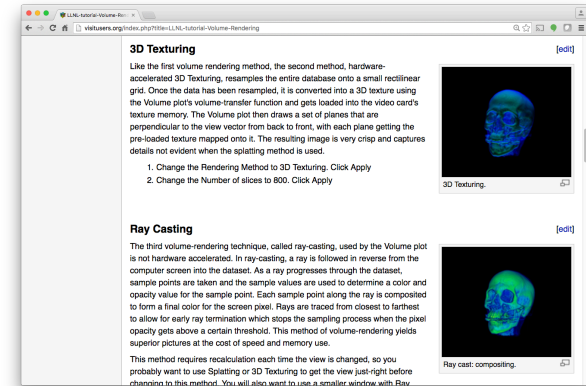
- The VisIt project started in 2000 to support LLNL's large scale ASC physics codes.
- The project grew beyond LLNL and ASC with research and development from DOE SciDAC and other efforts.
- VisIt is now supported by multiple organizations:
 - LLNL, LBNL, ORNL, UC Davis, Univ of Utah, Intelligent Light, ...
- Over 75 person years of effort, 1.5+ million lines of code.



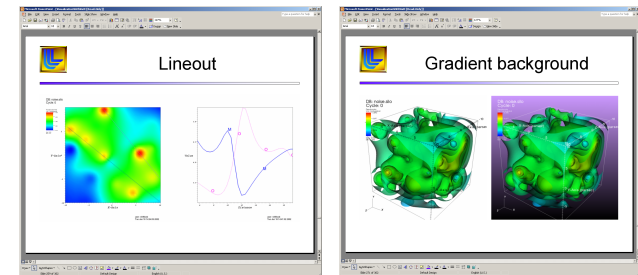


The VisIt team focuses on making a robust, usable product for end users.

- **Regular Releases (~ 6 / year)**
 - Binaries for all major platforms
 - End-to-end build process script ``build_visit``
- **User Support and Training**
 - visitusers.org, wiki for users and developers
 - Email lists: visit-users, visit-developers
 - Beginner and advanced tutorials
 - VisIt class with detailed exercises
- **Documentation**
 - Getting Data Into VisIt Manual
 - Python Interface Manual
 - Users Reference Manual



Tutorials on visitusers.org



VisIt class materials



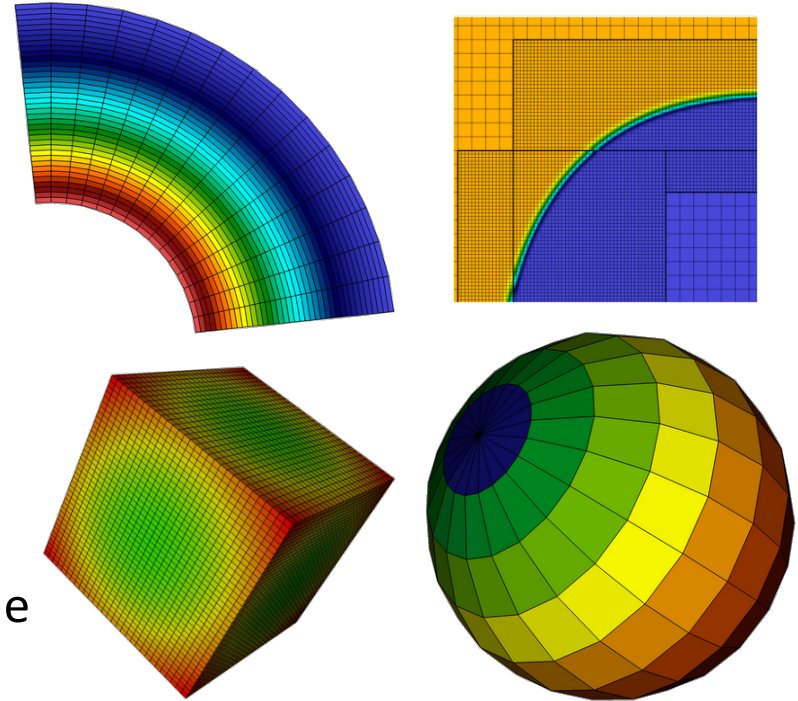
VisIt provides a flexible data model, suitable for many application domains.

■ Mesh Types

- Point, Curve, 2D/3D Rectilinear, Curvilinear, Unstructured
- Domain Decomposed, AMR
- Time Varying
- Primarily linear element support, limited quadratic element support

■ Field Types

- Scalar, Vector, Tensor, Material Volume Fractions, Species





VisIt supports more than 110 file formats.

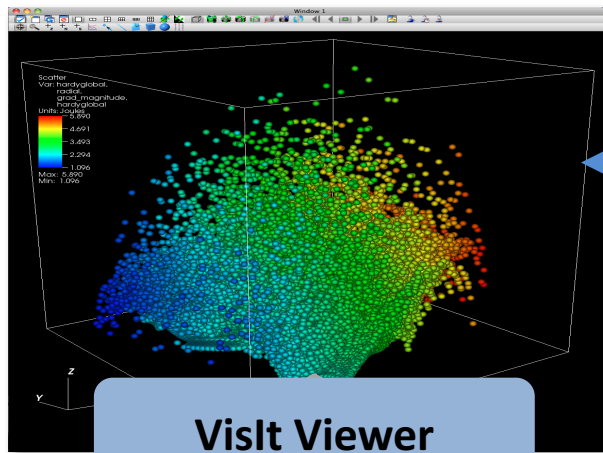
“How do I get my data into VisIt?”

- The *PlainText* database reader can read simple text files (CSV, etc)
 - [http://visitusers.org/index.php?title=Using the PlainText reader](http://visitusers.org/index.php?title=Using_the_PlainText_reader)
- Experiment with the *visit_writer* utility:
 - <http://visitusers.org/index.php?title=VisItWriter>
- Write to a commonly used format:
 - *VTK, Silo, Xdmf, PVTk*
- Consult the [Getting Data Into VisIt Manual](#) and its associated [source code examples](#).



VisIt employs a parallelized client-server architecture.

Client Computer



VisIt Viewer

VisIt GUI

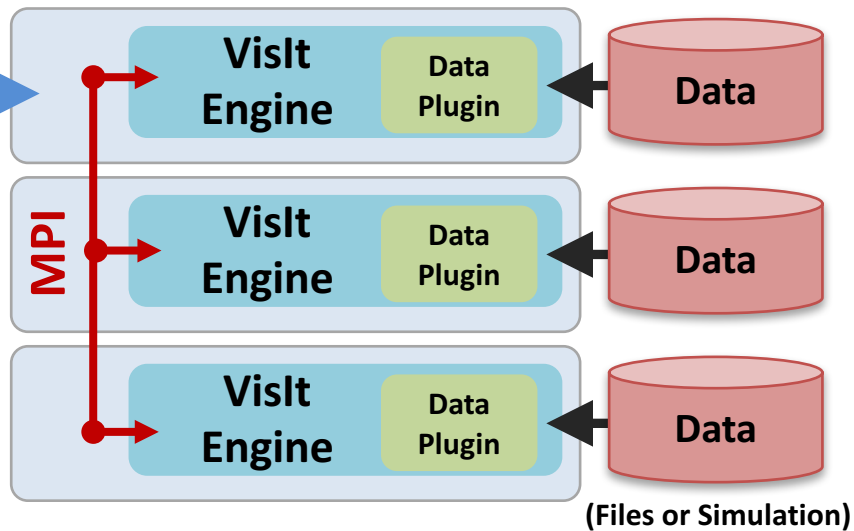
VisIt CLI

Python
Clients

Java
Clients

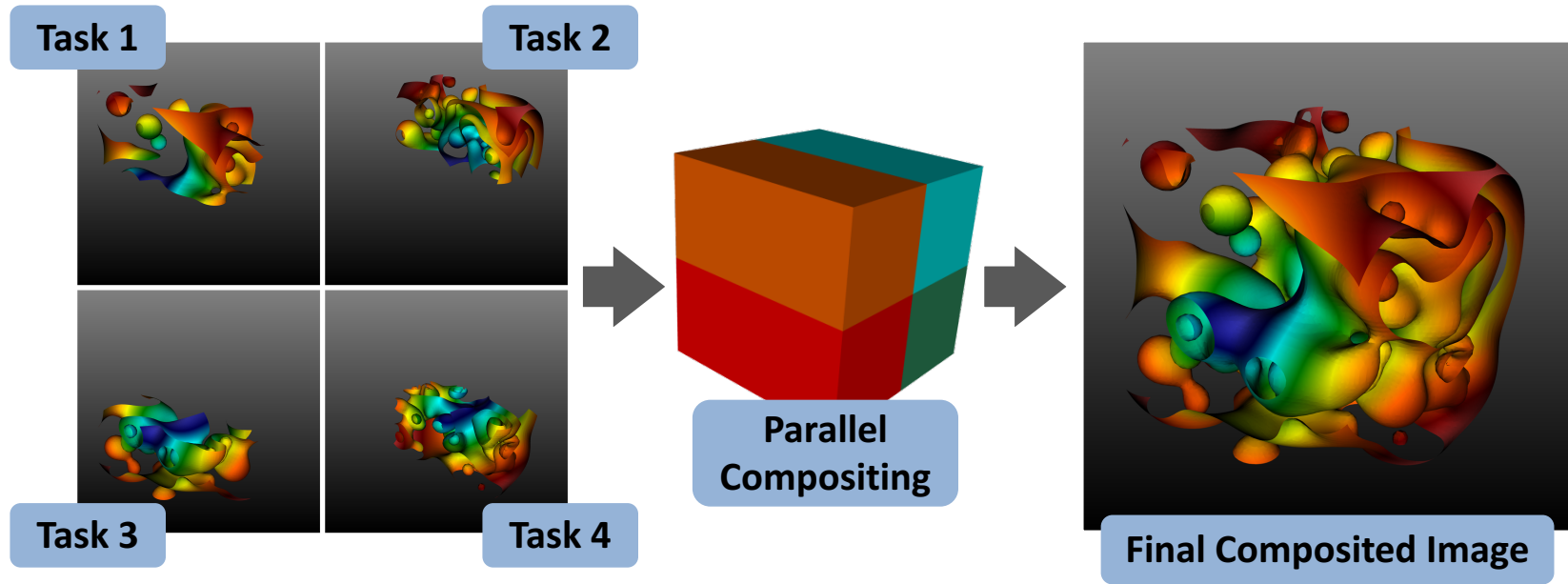
network
connection

Parallel HPC Cluster





VisIt automatically switches to a scalable rendering mode when plotting large data sets on HPC clusters.



In addition to scalable surface rendering, VisIt also provides scalable volume rendering.



VisIt's infrastructure provides a flexible platform for custom workflows.

■ C++ Plugin Architecture

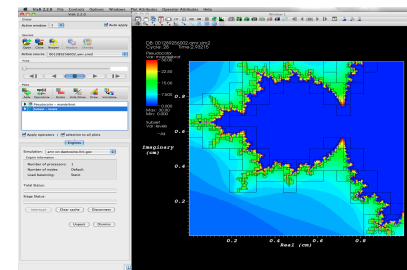
- Custom File formats, Plots, Operators
- Interface for custom GUIs in Python, C++ and Java

■ Python Interfaces

- Python scripting and batch processing
- Data analysis via Python Expressions and Queries

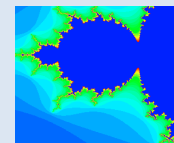
■ In-Situ Coupling

- VisIt's *Libsim* library allows simulation codes to link in VisIt's engine for in situ visualization



VisIt

Simulation



Libsim
Adaptor



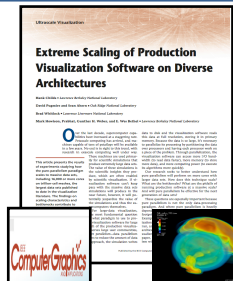
VisIt is used as a platform to deploy visualization research.

■ DOE ASCR Research Collaborations



■ Research Focus

- Light weight In Situ Processing
- Node Level Parallelism
- Distributed Memory Parallel Algorithms



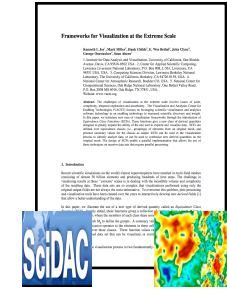
Scaling research
Scaling to 10Ks of cores and trillions of cells.



Algorithms research
How to efficiently calculate particle paths in parallel.



Algorithms research:
Reconstructing material interfaces for visualization



Methods research:
How to incorporate statistics into visualization.



VisIt is a robust, usable tool, that provides a broad set of visualization capabilities for of HPC simulation data.

- **Provides Features that span the “power of visualization”**
 - Data Exploration
 - Confirmation
 - Communication
- **Provides Features for different kinds of users**
 - Visualization Experts
 - Code Developers
 - Code Consumers

VisIt is actively developed and has vibrant developer and user communities.





Visualization Techniques for Mesh-based Simulations

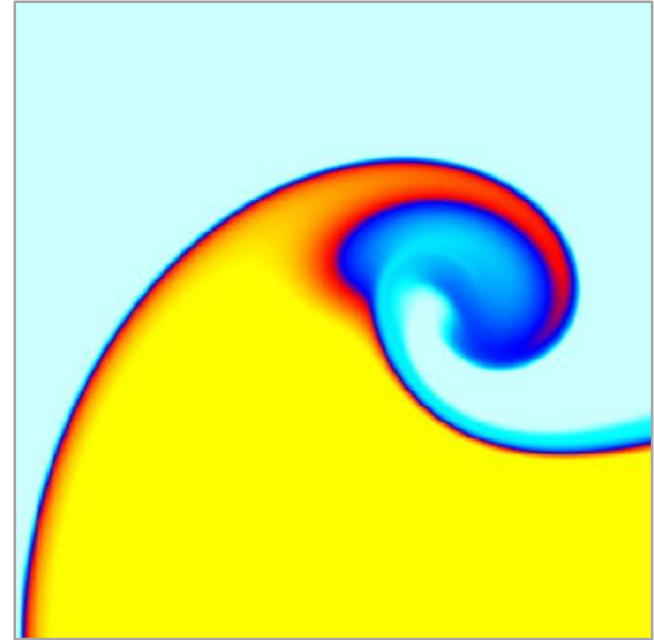




Pseudocolor rendering maps scalar fields to a range of colors.



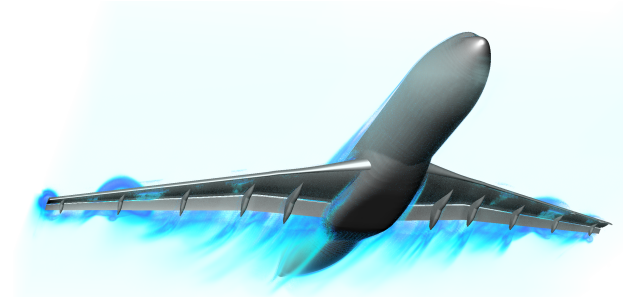
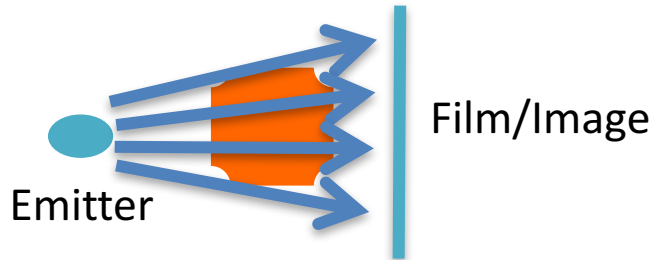
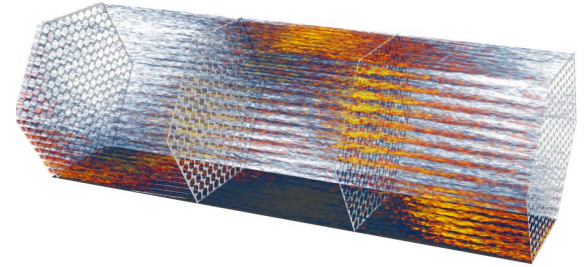
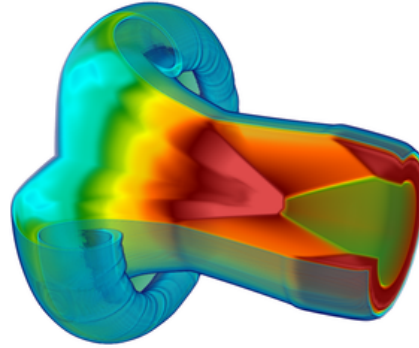
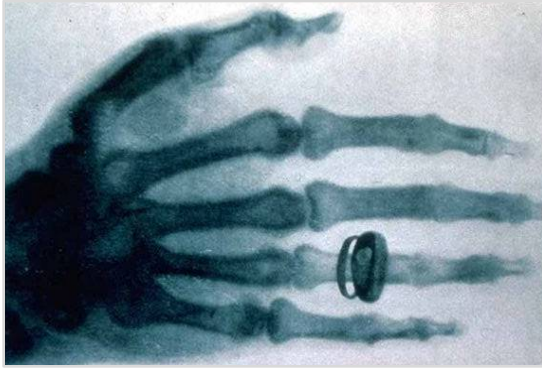
Pseudocolor rendering of Elevation



Pseudocolor rendering of Density

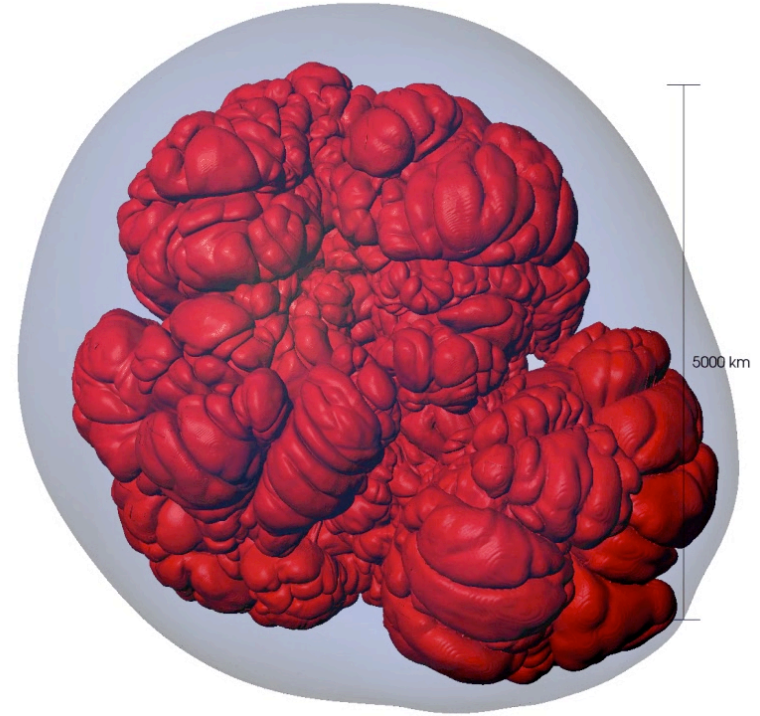


Volume Rendering cast rays through data and applies transfer functions to produce an image.





Isosurfacing (Contouring) extracts surfaces of that represent level sets of field values.

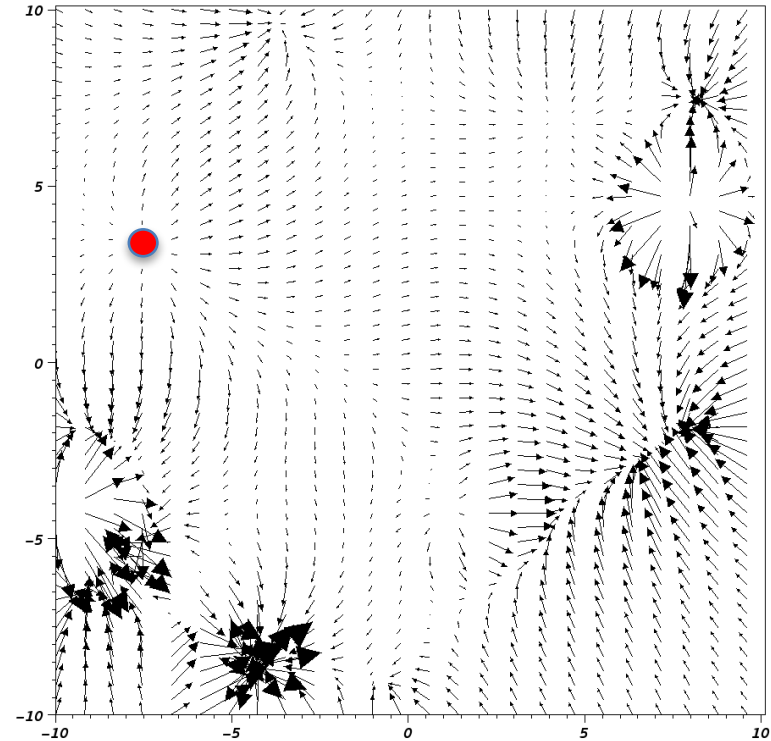




Particle advection is the foundation of several flow visualization techniques.

- $S(t)$ = position of particle at time t
- $S(t_0) = p_0$
 - t_0 : initial time
 - p_0 : initial position
- $S'(t) = v(t, S(t))$
 - $v(t, p)$: velocity at time t and position p
 - $S'(t)$: derivative of the integral curve at time t

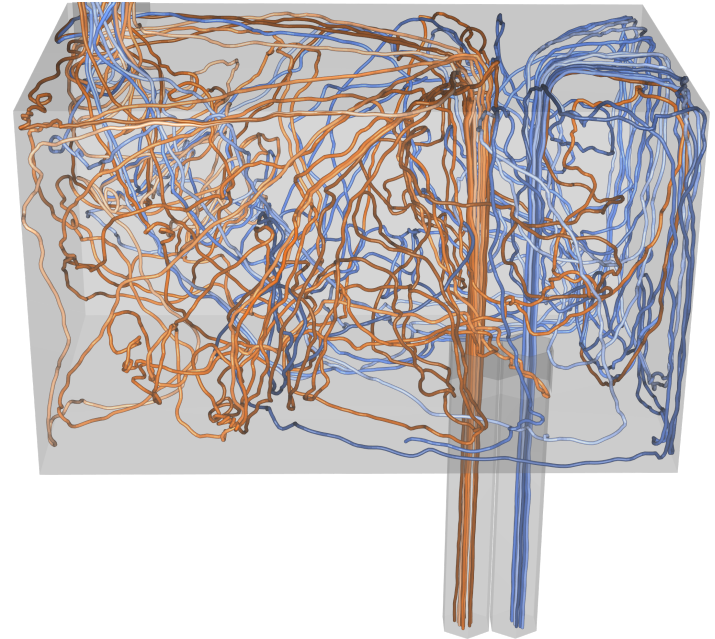
This is an ordinary differential equation.





Streamline and Pathline computation are built on particle advection.

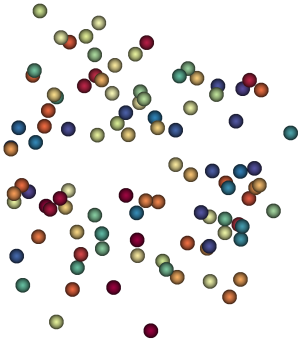
- **Streamlines** – Instantaneous paths
- **Pathlines** – Time dependent paths



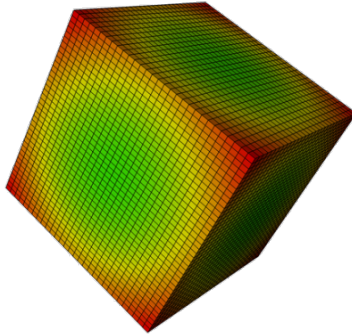


Meshes discretize continuous space.

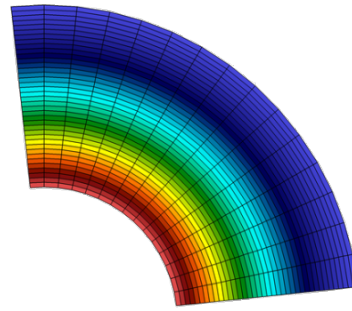
- **Simulations use a wide range of mesh types, defined in terms of:**
 - A set of coordinates (“nodes” / “points” / “vertices”)
 - A collection of “zones” / “cells” / “elements” on the coordinate set



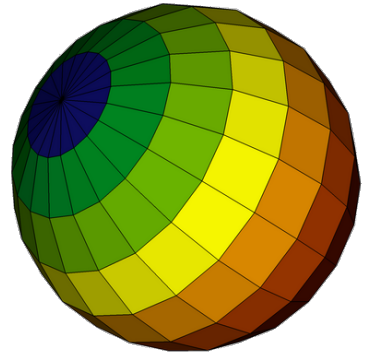
Points



Uniform



Curvilinear



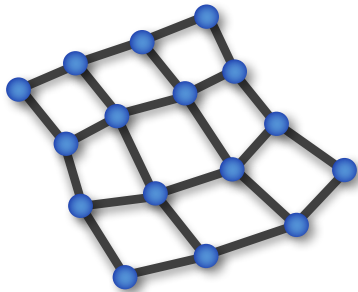
Unstructured

VisIt uses the “Zone” and “Node” nomenclature throughout its interface.

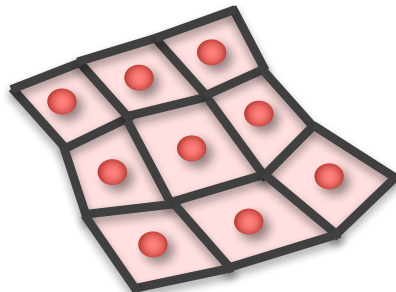


Mesh fields are variables associated with the mesh that hold simulation state.

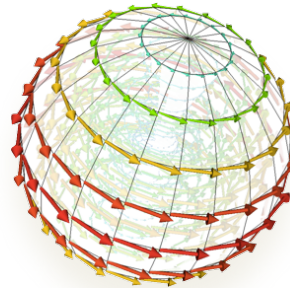
- Field values are associated with the zones or nodes of a mesh
 - Nodal: Linearly interpolated between the nodes of a zone
 - Zonal: Piecewise Constant across a zone
- Field values for each zone or node can be scalar, or multi-valued (vectors, tensors, etc.)



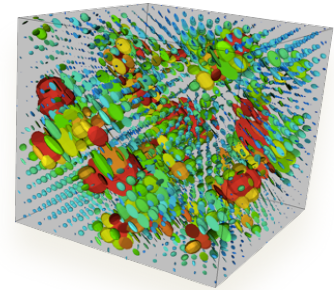
Nodal Association



Zonal Association



Vector Field

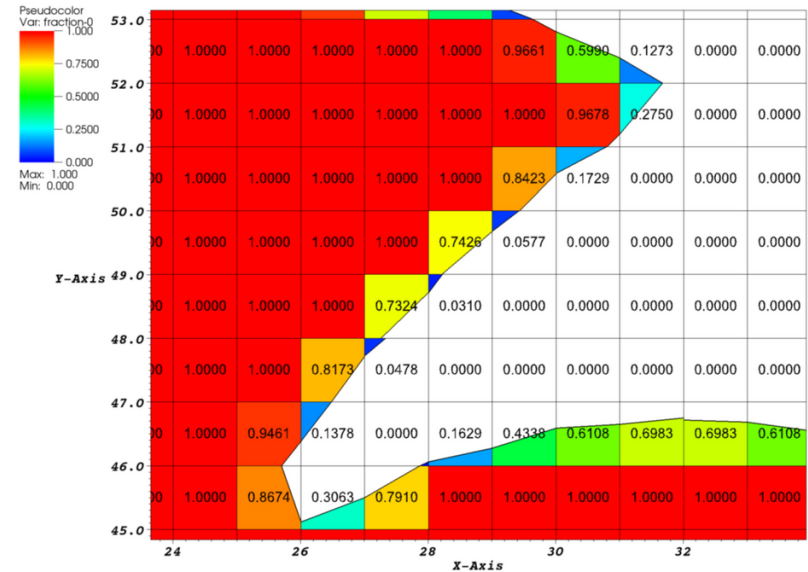


Tensor Field



Material volume fractions are used to capture sub-zonal interfaces.

- Multi-material simulations use volume/area fractions to capture disjoint spatial regions at a sub-grid level.
- These fractions can be used as input to high-quality sub-grid material interface reconstruction algorithms.





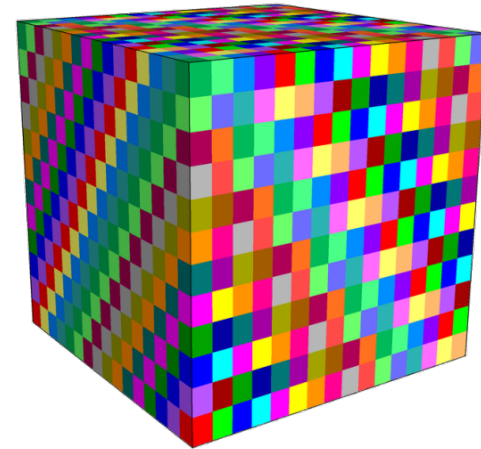
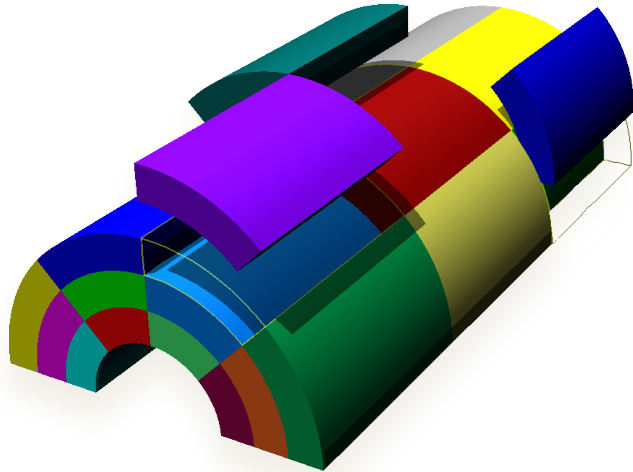
Species are used to capture sub-zonal weightings.

- Species describe sub-grid variable composition
 - Example: Material “Air” is made of species “N2”, “O2”, “Ar”, “CO2”, etc.
- Species are used for weighting, not to indicate sub-zonal interfaces.
 - They are typically used to capture fractions of “atomically mixed” values.



Domain decomposed meshes enable scalable parallel visualization and analysis algorithms.

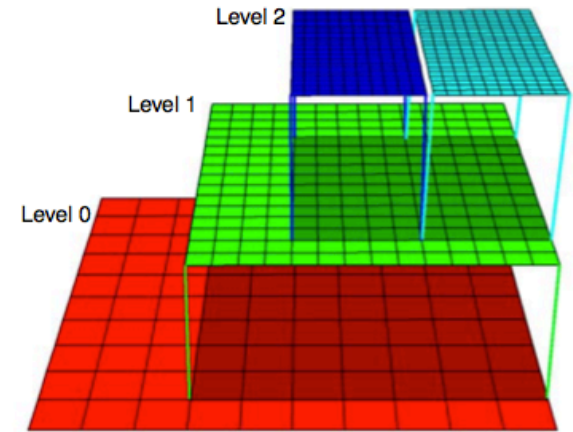
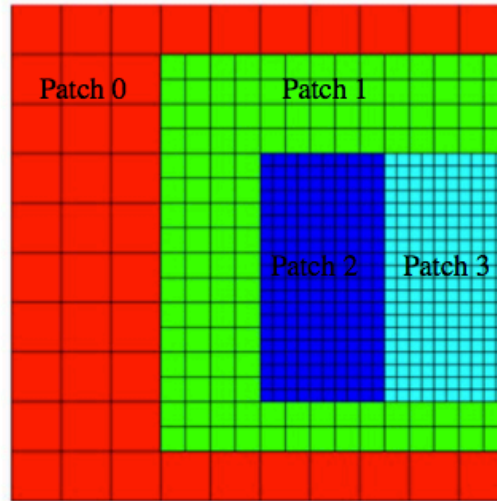
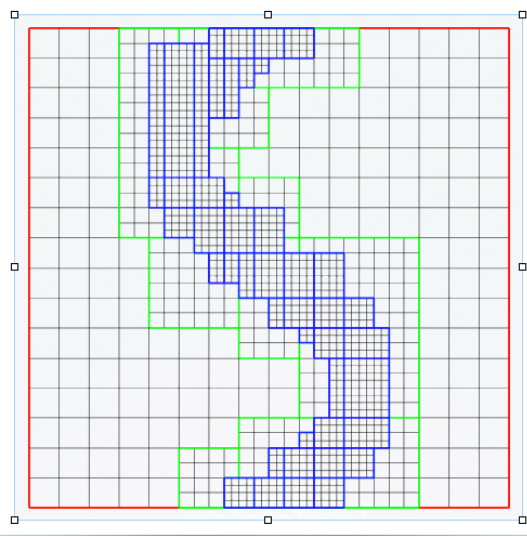
- Simulation meshes may be composed of smaller mesh “blocks” or “domains”.
- Domains are partitioned across MPI tasks for processing.





Adaptive Mesh Refinement (AMR) refines meshes into patches that capture details across length scales.

- Mesh domains are associated with patches and levels
- Patches are nested to form an AMR hierarchy





Guided Tour of VisIt

- **Materials from:**

- <http://visitusers.org/index.php?title=VisIt-tutorial-basics>
- <http://visitusers.org/index.php?title=VisIt-tutorial-data-analysis>
- <http://visitusers.org/index.php?title=VisIt-tutorial-Python-scripting>



VisIt's interface is built around five core abstractions.

- **Databases:** Read data
- **Plots:** Render data
- **Operators:** Manipulate data
- **Expressions:** Generate derived quantities
- **Queries:** Summarize data



Aneurysm Simulation Exploration

http://visitusers.org/index.php?title=Blood_Flow_Aneurysm_Tutorial



Additional Hands-on Materials

- **Water Flow Simulation Exploration**
 - http://visitusers.org/index.php?title=Water_Flow_Tutorial
- **Volume Rendering**
 - <http://visitusers.org/index.php?title=Visit-tutorial-Volume-Rendering>
- **Advanced Movie Making**
 - <http://visitusers.org/index.php?title=Visit-tutorial-Advanced-movie-making>



Resources

Presenter Contact Info:

- Kevin Griffin: griffin28@llnl.gov
- Cyrus Harrison: cyrush@llnl.gov
- Eric Brugger: brugger1@llnl.gov

User Resources:

- Main website: <http://www.llnl.gov/visit>
- Wiki: <http://www.visitusers.org>
- Email: visitusers@ornl.gov

Developer Resources:

- Email: visit-developers@ornl.gov
- SVN: <http://visit.ilight.com/svn/visit/>

