Analysis and Visualization of Terabyte-Scale Astrophysical Turbulent Combustion Datasets

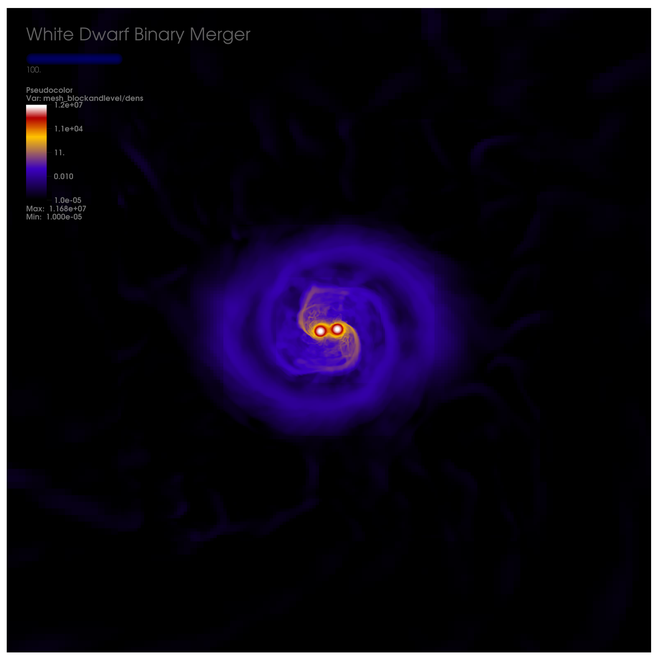
DEPARTMENT of SCIENTIFIC COMPUTING

Introduction

Complex simulations running on today's supercomputers can generate enormous data sets that contain trillions of bytes. To better understand these results, scientists and engineers often use visualization software to create pictures of the data that are far easier to interpret than reams of numbers. Problems that run for days or weeks on the world's most powerful supercomputers can now be visualized or analyzed in seconds using VisIt—a flexible visualization and analysis tool developed at Livermore. VisIt is used to visualize data from a wide range of simulation codes including computational fluid dynamics, finite-element analysis, astrophysics, and
climate research.

Visual renditions of data sets range from the simple, such as basic plots, to the highly complex, such as three-dimensional (3D) volume renderings, with color frequently used to explain the data's characteristics. VisIt can produce images, movies, and statistical reports.

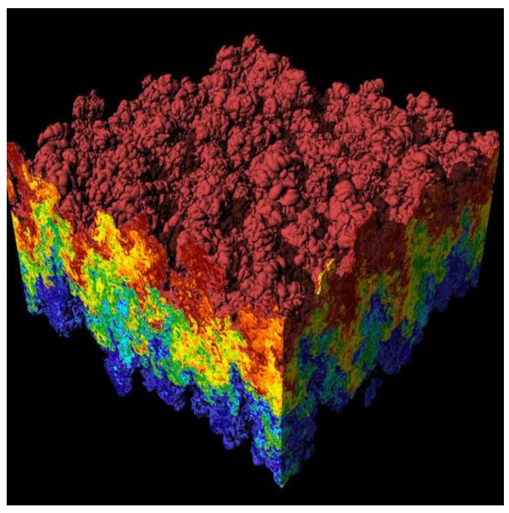
The visualization tool runs on various platforms from desktop computers to Livermore's Purple and Thunder supercomputers. Its three operating modes effectively use computing resources based on data-set size. For small- to medium-scale data sets, VisIt simply runs on a desktop machine. For larger scale sets, its work is distributed: Data are processed in parallel on a supercomputer, and surfaces are transferred back to a desktop machine for renderings. This mode leverages the best of both computing environments. On a supercomputer, large amounts of data are processed quickly through parallelization. The graphics card in a user's desktop computer provides the interactivity needed to examine data from different viewpoints. For the largest scale data sets, VisIt does all of the processing, including the rendering, on a supercomputer.



Astrophysics- White Dwarf Merger

Large scale simulations are very important in fields like astrophysics where the conditions and distances can be extreme and where very few direct measurements are available. Most of the science of astrophysics, before the advent of these large simulations, involved a lot ot time at a telescope and a lot of guesswork. Creating a simulation of a star allows physicists to test their theories on how materials at incredibly high densities and temperatures behave in a more controllable way. Instead of searching the skies to find a star that has the correct conditions to demonstrate their theory in action they can create one in the computer and see how it behaves given a set of conditions.

These images (left and below) are from a simulation done by Tomasz Plewa, of the FSU Department of Scientific Computing and Artur Gawryszczak, Nicolaus Copernicus Astronomical Center, Warsaw, Poland. The simulation was of two white dwarf stars orbiting each other, with the more massive star eventually consuming the other.

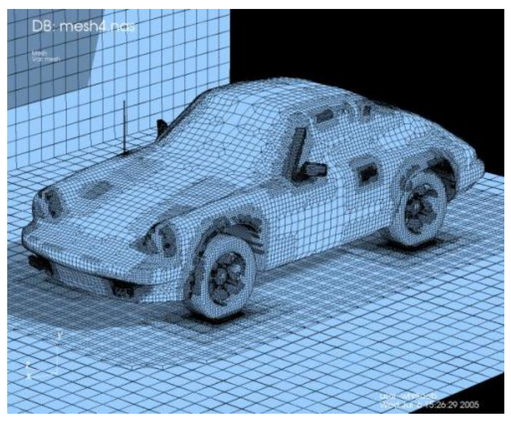


Raleigh-Taylor instability (Fluid flow instabilities)

This visualization shows a Pseudocolor plot that highlights a Raleigh-Taylor instability caused by two mixing fluids of different densities.

NASTRAN model

The featured plot contains a Mesh plot of a Porsche 911 model imported from a NASTRAN bulk data file. VisIt can read a limited subset of NASTRAN bulk data files, generally enough to import model geometry for visualization.



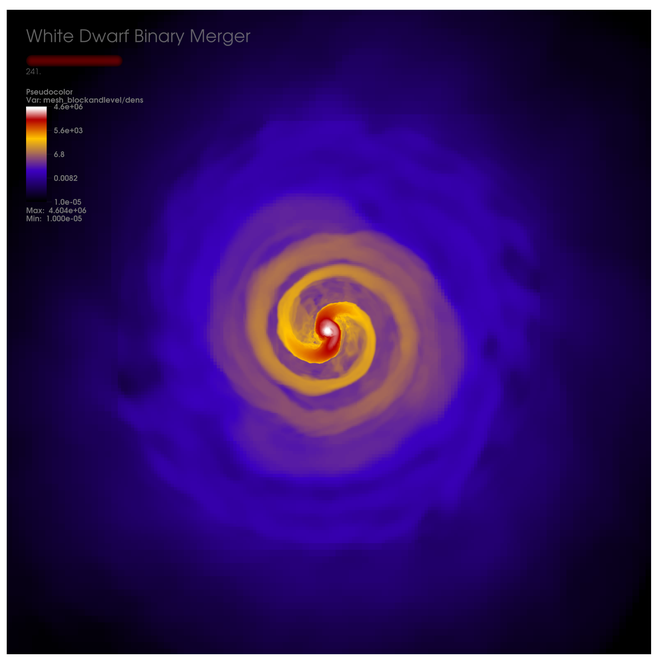
FVCOM Gulf of Maine Simulation Snapshot of Density and Velocity

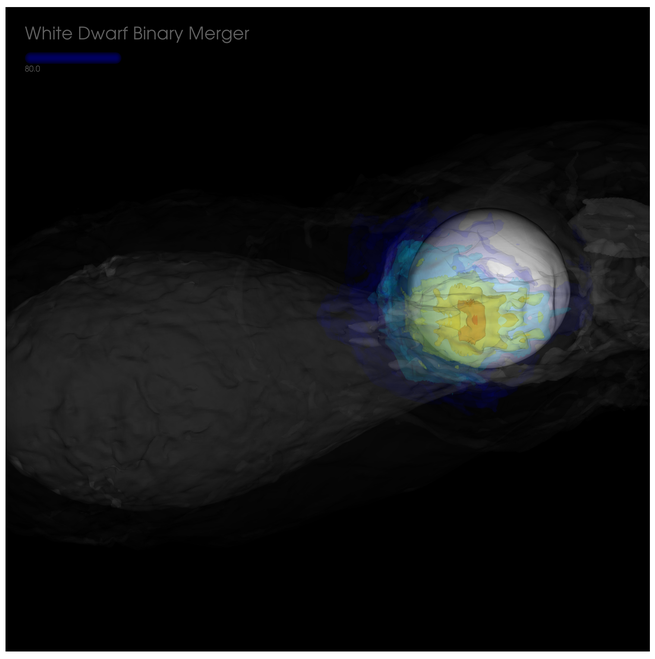
Finite Volume Coastal Ocean Model is a prognostic, unstructured-grid, free-surface, 3-D primitive equation coastal ocean circulation model developed at UMASSD and WHOI. VisIt draws FVCOM data from a 2 year Gulf of Maine simulation during a rising tide in August of 1999. The bathymetry is shown in gray while the sea surface is transparent blue. A surface of constant density (1025 kg m-3) is transparent orange with its intersection on two vertical sections is shown in black. The vectors show a few of the model velocities on the constant density surface as the rising tide rushes in to fill the gulf of Maine.

Image courtesy of David Stuebe from Chen's Lab at University of Massachusetts, Dartmouth.

The images in this column are shown from a perspective point above the plane
Of rotation at various times in the evolution of this system. The top image is from 100 seconds into the simulation. Initially there is none of the gas or structure you can see around the white dwarf stars themselves even at this early time. The system evolves very quickly under these conditions.

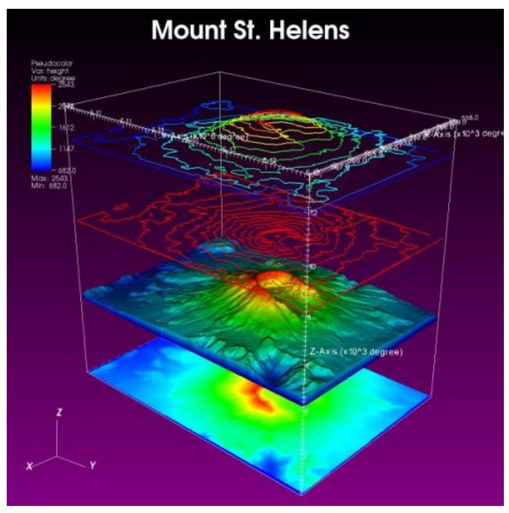
Below this are two images from the same time, but with different information shown. The first image shows a density surface, with more dense areas appearing white and less dense areas showing blue or black. Also inthis image you can see the adaptive mesh that was used in the creation of this simulation as a coarse blocky area around the edges, with the elements becoming smaller as you approach the more turbulent area near the center. This allows us to save on computational time by concentrating on the area of interest and spending less time on areas where not much is happening.





The images in this column show the same system as in the column to the left, but with a different perspective and at much earlier times. The image above is taken at 80 seconds, and the one below at 96 seconds. The partially-transparent white surface is a specific density chosen to reveal the size and position of the densest parts of the stars without allowing them to occlude other structures in the system.

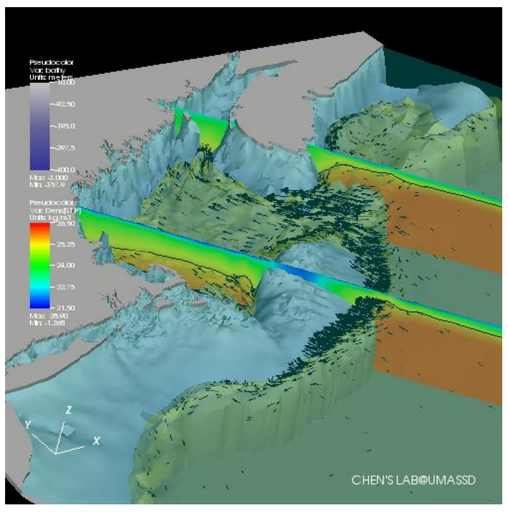
The above image shows the heavier of the two white dwarfs making very quick progress in absorbing its smaller companion. The image below shows that even just a minute and a half in the smaller star no longer even has a spherical shape.

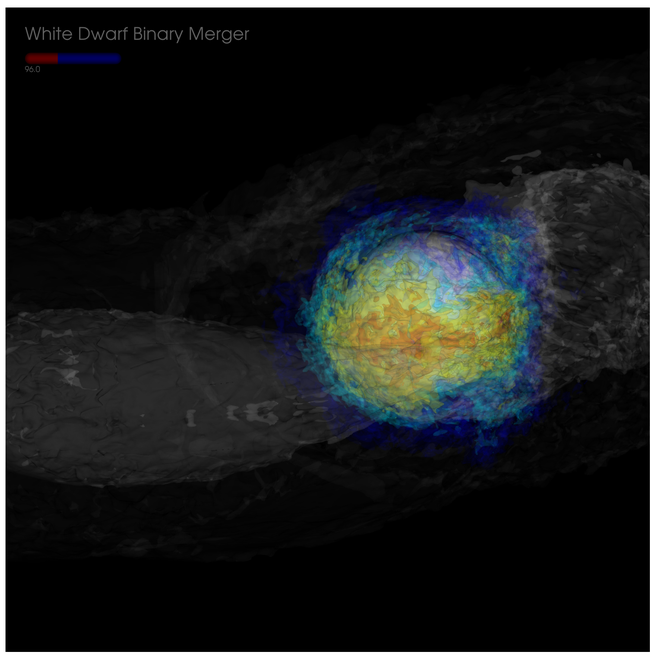


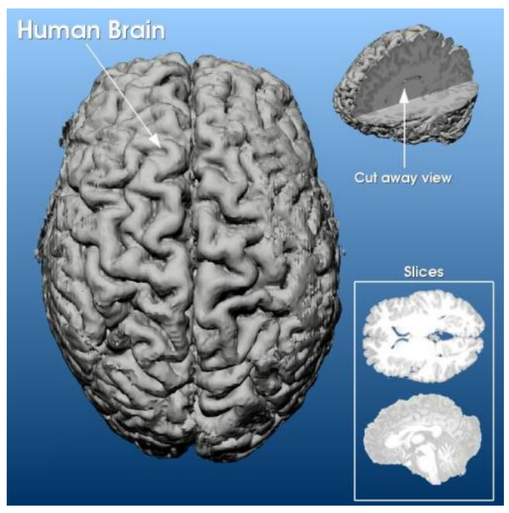
Multiple plots

VisIt can put multiple plots in a single visualization, allowing you to visualize data in multiple ways. The featured image shows four representations of Mount St. Helens elevation data from a DEM file.

The DEM dataset used to create the featured image was obtained from the USGS.







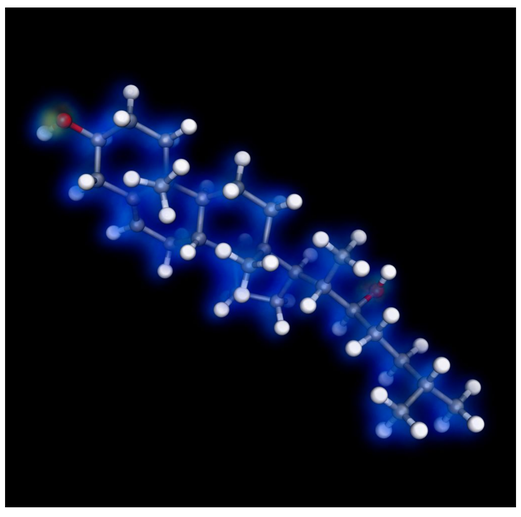
Brain visualization

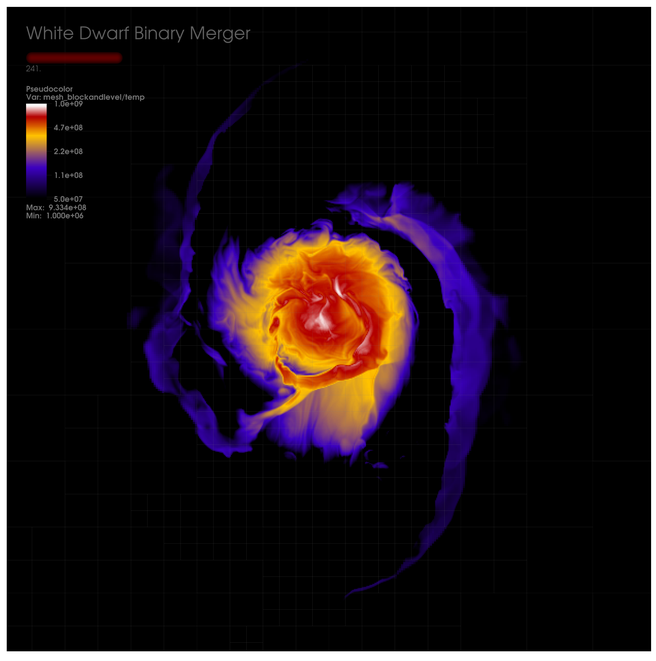
The featured visualization includes multiple views of a human brain dataset, stored in the ANALYZE file format, that was originally obtained by MRI.

The ANALYZE dataset used in the visualization was provided by James E. Dobson of the Psychological and Brain Sciences faculty at Dartmouth College.

Structure and charge density

The image to the left shows the structure and charge density of a cholesterol derivative calculated using the VASP code. Image courtesy of Paul Kent at Oak Ridge National Laboratory.





Acknowledgements

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Special thanks as well to Visit user support guru Hank Childs for all his efforts in getting these complex images rendered correctly.

Poster created by Bert Green for the 2010 Computational Science Expo