MADAI: Modeling and Data Analysis Initiative

Department of Computer Science | University of North Carolina at Chapel Hill | August 2010

About

The Modeling and Data Analysis Initiative (MADAI) grew from an NSF-sponsored collaboration between Michigan State University, Duke, the Renaissance Computing Institute (RENCI), and UNC to include NCSU, Sandia National Laboratories, and Kitware, Inc. Our goal is to develop new visual and statistical analytics tools for a range of scientific disciplines and to deploy them in a unified scientists' workbench. Funding from NSF and Sandia supports the large team, seen at the bottom of the page (taken at our Spring 2010 team meeting in Albuquerque), that includes domain scientists studying universe formation, galaxy formation, supernovae, weather simulation, and high-energy particle collision as well as a multi-institutional team of statisticians and a multi-institutional visualization team.

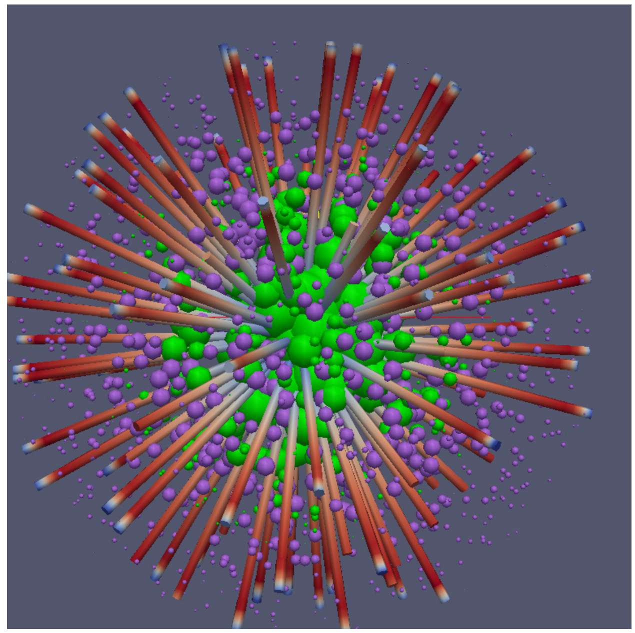
Our approach is to extend the open-source ParaView visualization framework to add new capabilities and custom plug-ins to meet the needs of our five domain-science collaborators. We are also providing workflow hooks to their existing tools: Matlab, R, and Root.

Domain Science Goals

Starting from the small scale and moving upward, the five domain-science areas we are addressing include:

High-energy physics particle collisions

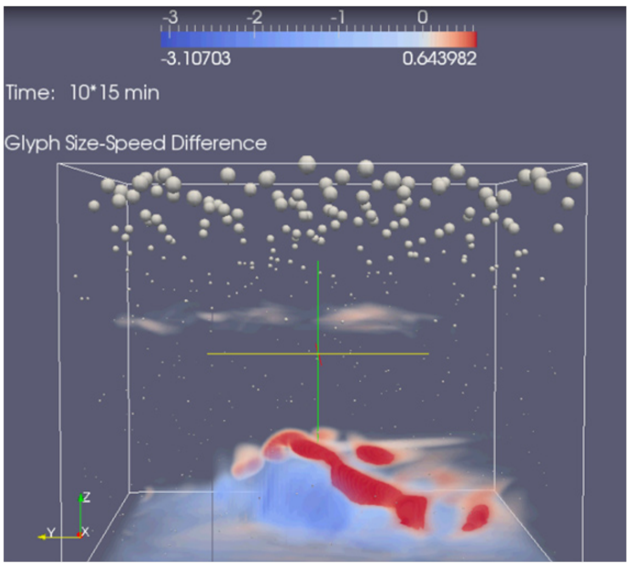
We are working with Scott Pratt (MSU) and Steffen Bass (Duke) on this project. The overall goal of this project is to produce a fundamental physical model of the behavior of quark-gluon plasma (QGP) and determine the values of relevant parameters in that model. The basic approach is to utilize various models (fluid dynamics, particle, and hybrid) to simulate the dynamics of the QGP to determine which model produces output particle distributions most like those seen in experiments. The parameter values of that "best-fit" model can then be used to gain novel physics insight.



The image above shows a prototype visualization of such a collision, developed by graduate students Serdar Cakici, Mitchell Cobb, Vincent Jacobucci, Kevin Macon, and Carlowen Smith as part of their final project in the **Visualization in the Sciences** class in the spring of 2010. It shows the results of a simulated collision between two clumps of gold atoms. The lines coming from the center show the plasma exploding out from the collision with speed mapped to color (blue at the tips indicating rapid deceleration). The size of the purple and green spheres indicates the energy density and temperature. It shows that they are positively correlated, with temperature (green) dropping off more rapidly than energy density. This image is one frame from an animation that shows the entire dynamic process of the collision.

Weather

We are working with Sharon Zhong (MSU) on this project. We are targeting several existing and upcoming studies: weather (especially cloud formation) within bowl-shaped features, wind patterns (especially rotors) near mountains, and controlled-burn smoke transport. In each case, there are experimental measurements of actual weather events and a number of simulation models that can be applied. There are two major steps to this research: (1) determining which model and which set of model parameters provide the best fit to experimental data for a given location, and (2) using the resulting best-fit simulation to determine the effects of terrain and initial conditions on weather behavior at that location. The best-fit model acts as a mechanism for data interpolation between the experimentally measured data points.



The image above shows a differential visualization between two simulation runs with slightly different parameters. This is a single frame from an animation that shows the entire dynamic difference between the simulations. The wind-speed difference is indicated by the size of spheres within the volume, showing that the wind speeds differed the most at upper elevations. The volume rendering shows temperature difference, and shows whether the temperature in the second simulation is lower (blue) or higher (red) than in the first.

Galaxy Formation

We are working with Brian O'Shea (MSU) on this project. The primary approach being taken to study the formation of the Milky Way is to do detailed dark-matter simulations and then statistical simulations on the resulting tree of particle trajectories, comparing the resulting distribution of stars and gas to that of the Milky Way. The main hypothesis is hierarchical structure formation whereby smaller groupings agglomerate to make larger structures. The overall goal is to understand what are the most-likely star/gas mixture parameters for structure formation of our galaxy, and how sensitive the resulting structure is to each of these parameters. We also want to explain the categories of abundance mixtures (distribution of carbon/hydrogen to iron/hydrogen ratios, etc.) Where does a set of abundances come from -- white dwarfs, supernovae, etc?

Universe Formation

We are working with Mark Voit (MSU) on this project. Our collaborators are beginning to perform large sky surveys looking at galaxy clusters. Models predict how many clusters should occur at different distances depending on how much dark matter/energy there is in the universe. They can simulate these models to see what hypothesized universes would look like. The main approach is to compare these simulated universes to the cluster surveys. The main goal is to determine how best to perform a sky survey so that it will provide good discrimination between different proposed cosmological models, and so that it will enable accurate determination of the parameters of those models. They want to guide the design of an ongoing survey so that it will maximally discriminate between model parameter values.

Project Members

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