Annual Report for NCC5-613: A C++ Framework for Block-Structured Adaptive Mesh Refinement Methods

July 12, 2004

This report covers the period from 10/2002 to 7/2004.

Objective

The objective of this work is to develop a software framework for implementing block-structured AMR algorithms, based on the Chombo C++ framework for AMR applications developed at at LBNL. This framework includes support for the applications of multiphase flow in microgravity environments and star formation, and a visualization and data analysis toolkit.

Approach

The design approach is based on two ideas. The first is that the mathematical structure of the algorithms maps naturally into a combination of data structures and operations on those data structures which are embodied in C++ classes. The second is that the mathematical structure of the algorithms can be naturally factored into a hierarchy of abstractions, leading to an analogous factorization of the framework into reusable components, or *layers*. Functionality within a layer results from a combination of generic proramming and sub-classing. For visualization and data analysis, this approach is combined with the use of Python and TKInter to provide a GUI and interpretive command-line interface for performing these tasks. Finally, all of the tools developed here will be built on top of widely-available software platforms: C++ and Fortran 77 compilers and the Python interpreter, MPI for distributed-memory parallelism, HDF5 for parallel I/O, and the VTK visualization toolkit.

Scientific Accomplishments

There were no scientific accomplishments in the time period covered by this report.

Technology Accomplishments

1. Completion of complete high-level algorithmic and API specifications for AMR fluid dynamics codes in support of the microgravity and star formation applications as required under Milestone H, including algorithm and software design documents. Acceptance of Milestone H by NASA program management.

2. Completion and release of code performance improvements as required under Milesstone F, including code and supporting documentation. Acceptance of Milestone F by NASA program management.

3. Implementation of improved advection solver for AMR Navier-Stokes code which resulted in better accuracy in three dimensions and which leveraged the existing hyperbolic infrastucture for use in the incompressible code.

4. Completion and release of preliminary implementations of code for parts of microgravity applications as specified in Milestone I. Acceptance of Milestone I by NASA program management. Sample pyChomboVis visualizations of examples of these implementations appear in Figures 1 and 2.

5. Completion of the ehancements to ChomboVis required for milestones O1, O2, and O3. This includes documentation of the requirements derived from discussions with potential NASA users of the ChomboVis software (Milestone O1-1), as well as user documentation (Milestone O2-4, O3-3); enhancements of the visualization capabilities (Milestones O2-2, O3-2); design and preliminary release of a data analysis capability (Milestones O2-1, O3-1); and a C / Fortran 77 I/O interface to the

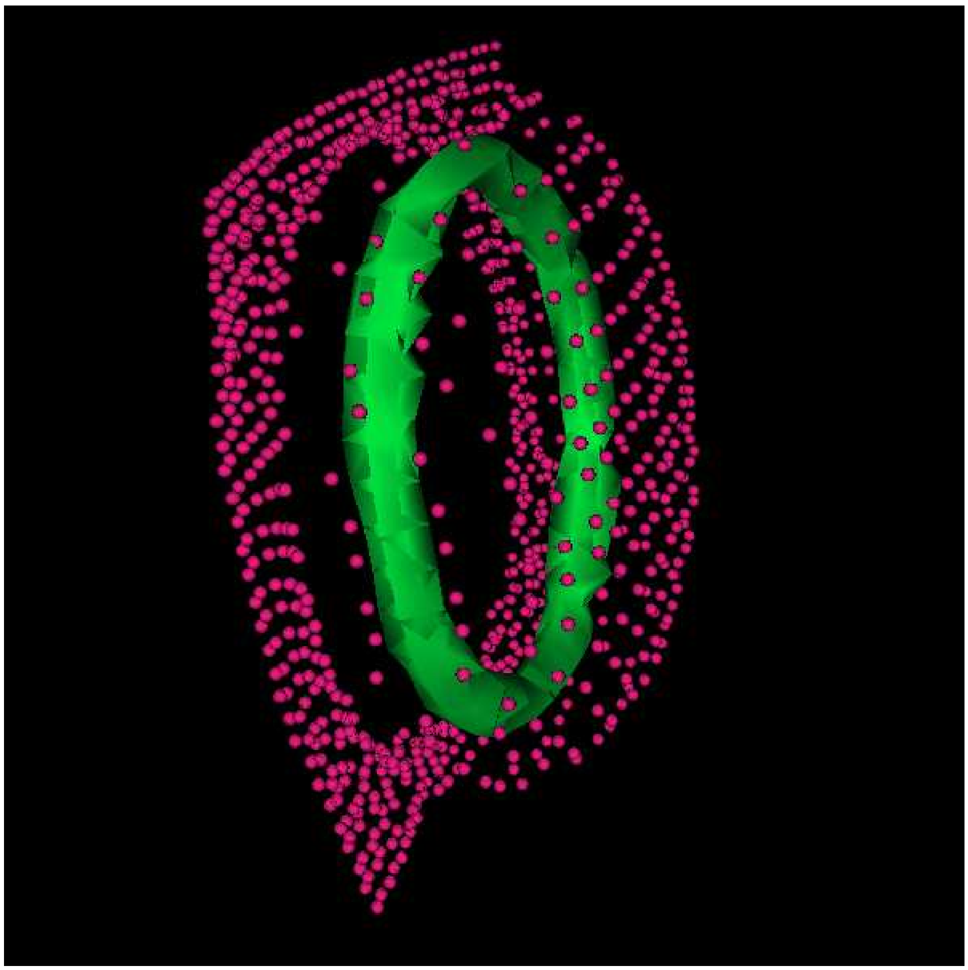

Figure 1: Visualization of a vortex ring interacting with suspended drag particles, the benchmark problem for the AMR Navier-Stokes code with particles code, using pyChomboVis.

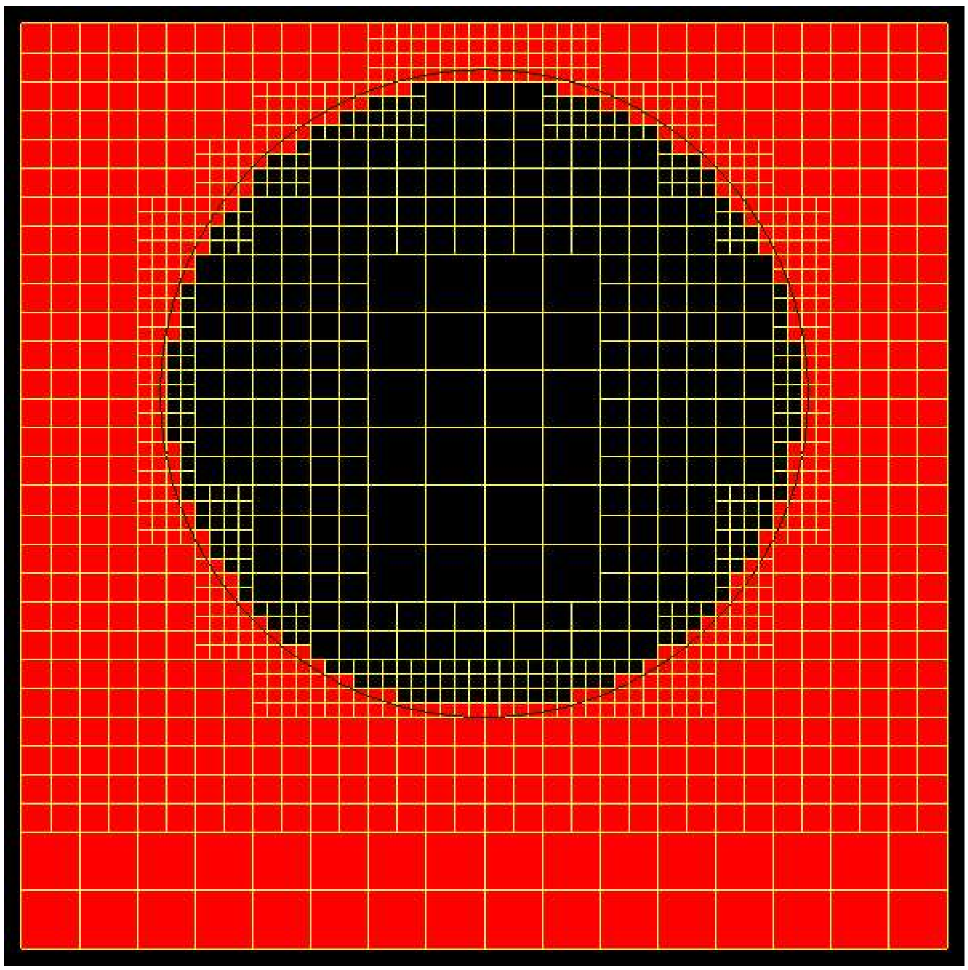

Figure 2: pyChomboVis visualization of 2D slice of a 2-phase multifluid spherical interface.

HDF5 parallel I/O to enable non-Chombo users to write ChomboVis-readable files from other block-structured AMR frameworks (Milestone O2-1).

Status / Plans

During the next fiscal year, we will undertake the following activities.

We will improve the performance of the components delivered in Milestone I and release these codes along with user documentation as required in Milestone G.

We will complete the various enhancements in ChomboVis described in milestones O4, and O5. This includes revision of the analysis tools presented in Milestone O3 based on feedback from the user community (Milestone O4-1), improved visualization capabilities including vector visualization and presentation graphics (Milestone O4-2), and the design and implementation of Terascale data capability, including out-of-core capability and SMP parallelism (Milestones O4-3, O5-1). This will result in a release of the final version of ChomboVis, including updated user documentation (Milestone O5-2).

We will use the infrastructure delivered in Milestone I to develop a multi-fluid interface tracking code (AMR-MFINS), which will include development of multi-fluid elliptic and hyperbolic solvers (MFElliptic and MFHyperbolic) and integration of these libraries into a code for incompressible two-phase flow with surface tension. as required in Milestone J.

Also, as required by Milestone J, we will develop coupled hyperbolic and self-gravity (AMR-SG) and MHD (AMR-MHD) versions of the existing hyperbolic AMRGodunov code.

Finally, we will improve the performance of the AMR-MFINS code developed for Milestone J and publically release this code along with user documentation as required by Milestone K.

Point of contact

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List of Publications

Crockett R. K., Colella P., Fisher R. T., Klein R. I., and McKee C. F., "An Unsplit, Cell-Centered Godunov Method for Ideal MHD." J. Comput. Phys., submitted

List of Conference Presentations

- Daniel Martin: ACTS Toolkit Meeting, Berkeley, CA August 5-8. 2003.

List of Patents Filed

There were no patents filed during the period covered by this report.

List of Graduate Students or Postdocs Trained

Name	Dates	Status	Department
Robert Crockett	8/2003-5/2004	Graduate Student	Physics
Pak-Shing Li	8/2003-present	post-doc	Astronomy