A Common Data Management Infrastructure for Parallel Adaptive Algorithms for PDE Solutions

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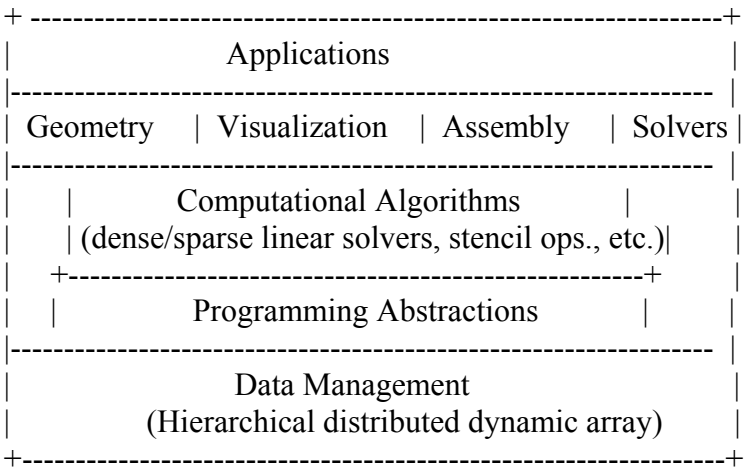
(I) Overview:

This paper will define, describe and demonstrate the application of a data management and programming abstraction infrastructure for development of applications based on parallel adaptive methods. The goal for this research is to reduce the intrinsic coding complexity of parallel adaptive algorithms by providing an appropriate set of data structures and programming abstractions.

The infrastructure has been developed as a result of collaborative research among computer scientists, computational scientists and application domain specialists working on three different projects: A DARPA project for hp-adaptive computational fluid dynamics and two NSF sponsored Grand Challenge projects, one for numerical relativity and another on composite materials. This collaboration is of critical importance to the development of the infrastructure. It has been repeatedly discovered during the development to date that the applications cannot foresee their requirements for implementation of a given method prior to implementation and that the computer and computational scientist cannot predict what is needed for the implementation of a given method.

(II) Conceptual Framework:

The figure below is a schematic of our perception of the structure of solution codes for sets of partial differential equations.



This paper is primarily concerned with the bottom two layers of this hierarchy and how these layers can support implementation of higher levels of abstraction. These two layers are:

1) A data management layer which implements a distributed and dynamic array, and

2) A programming abstraction layer which implements data abstractions such as grids, meshes and trees which underlie different solution methods. The clean separation of array

semantics from higher level operations is critical to the success of this approach in providing a common foundation for several different solution methods. Each project used a different adaptive solution method.
The data management infrastructure is founded on the observation that several different adaptive methods for solution of partial differential equations have a common set of requirements for management of the dynamic distributed data structures which ensue from the adaptations and parallelization.In particular it will be shown that all of finite difference methods based on adaptive mesh refinement, hp-adaptive finite element methods and adaptive fast multipole methods for solution of linear systems can readily be implemented on the hierarchical dynamic distributed array (HDDA) data structure.

(III) Status:
The data management and programming abstraction infrastructure is being used by the numerical relativity Grand Challenge and by several other projects