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MS07 Parallel Finite Element Software

Organized by: Peter Bastian, Christian Wieners

The numerical solution of partial differential equations by the finite element methods consists of a number of steps where the efficient resolution of linear systems by domain decomposition methods is an important but not the only part. The flexible and efficient implementation of all aspects of the finite element method on parallel computers has lead to increasingly complex software frameworks. In this minisymposium several new developments will be presented.

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Krzysztof Banaś

A Model for Parallel Adaptive Finite Element Software

Location: Room 005, **Time:** Wednesday, 23 July, 11:00

The paper presents a conceptual model and details of an implementation for parallel adaptive finite element systems, particularly their computational kernels. The whole methodology is based on domain decomposition while message passing is used as a model of programming. The proposed finite element architecture consist of independent modules, most of them taken from sequential codes. The sequential modules are only slightly modified for parallel execution and two new modules, explicitly aimed at handling parallelism, are added. The new modules comprise domain decomposition manager and parallel communication library interface.

The presented principles are thought of as a general guidance for the parallelization of sequential finite element codes. An example implementation utilizes 3D prismatic meshes and discontinuous Galerkin approximation. Two numerical examples, the first in which Laplace's equation is approximated using GMRES with multi-grid preconditioning and the second where dynamic adaptivity with load balancing is utilized for simulating linear convection, illustrate capabilities of the approach.

Christoph Pflaum

Parallelization Concepts of the Library EXPDE

Location: Room 005, **Time:** Wednesday, 23 July, 11:25

The aim of the library EXPDE is to provide a user friendly interface for the implementation of PDE software. The interface uses a language which is close to the mathematical language. Efficiency is obtained by expression templates. In this talk, we explain the parallelization concept and coarse grid correction of EXPDE. The parallelization properties are described for different concepts as block structured parallelization and parallelization of semi-unstructured grids.

[1] C. Pflaum, *Expression Templates for Partial Differential Equations*. Comput Visual Sci, Volume 4, Issue 1, pp.1-8, 2001.

[2] C. Pflaum, *Semi-Unstructured Grids*. Computing, Nummer 2, vol. 67, pp. 141-166, 2001.

[3] A. Linke, C. Pflaum, B. Bergen, *Scientific Progress in the Par-EXPDE-Project*, Preprint No. 246, Mathematische Institute, Universität Würzburg, 2002.

Christian Wieners

Distributed Point Objects: A New Concept for Parallel Finite Elements

Location: Room 005, **Time:** Wednesday, 23 July, 11:50

We present a new concept for the realization of finite element computations on parallel machines which is based on a dynamic data structure address by points. All geometric objects (cells, faces, edges) are referenced by its midpoint, and all algebraic data structures (vectors and matrices) are tied to the nodal points of the finite elements. Together, they build Distributed Point Objects (DPO), where the parallel distribution is made transparent by processor lists assigned to the points. All objects are stored in hash tables (where the keys are points) so that pointers can be completely avoided.

The purpose of our new model and its prototype implementation is to provide a platform for developing, testing, and improving lean interfaces between specific problem classes and general parallel solver. It represents a compromise between flexibility and compactness of the code and the requirements for an optimal performance. So, we avoid constructions which are machine dependent, and we restrict ourselves to a very small set of parallel commands in the message passing interface.

Finally, we consider the application of the parallel programming model to a geomechanical porous media problem (cooperation with Ehlers / Ammann, Universität Stuttgart). This demonstrates that demanding 3-d nonlinear and time-dependent engineering applications on unstructured meshes can be parallelized very efficiently within a very small overhead for the parallel implementation.

[1] C. Wieners, M. Ammann, W. Ehlers. *Distributed Point Objects: A new concept for parallel finite elements applied to a geomechanical problem.* 2003 (submitted to Future Generation Computer Systems)

Peter Bastian

Towards a Unified Framework for Finite Element Computations
Location: Room 005, **Time:** Wednesday, 23 July, 12:15

Finite Element implementations range from small and simple model problem applications to large frameworks incorporating many different finite element variants, state-of-the-art solvers, adaptive mesh refinement and parallel computation capability. The large frameworks typically have evolved over many years, are difficult to use and may be inefficient for particular applications with respect to memory and run-time.

In this talk we present an object oriented approach to finite elements that is intended as an open, public domain software platform. Its particular features are: (1) Flexibility (higher order, systems, adaptivity, parallelism), (2) reusability of old code (E.g. Albert, UG) and (3) efficieny. These features are achieved through the use of static polymorphism.

The talk discusses the design of the code with emphasis on the grid abstraction. Already existing applications include a large scale explicit finite volume scheme and a parallel algebraic multigrid solver. Both codes are used to illustrate the concept.

This is joint work with M. Blatt (Heidelberg), M. Droske (Duisburg), C. Engwer (Heidelberg), R. Klöfkorn (Freiburg), M. Ohlberger (Freiburg) and M. Rumpf (Duisburg).