Hypre: High Performance Preconditioners

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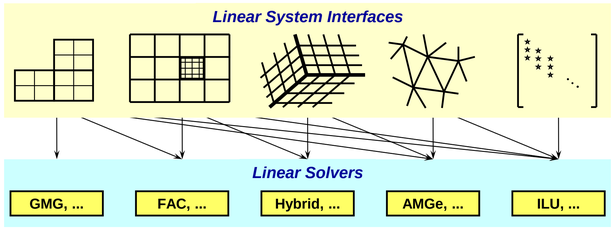
The hypre software library provides high performance preconditioners and solvers for the solution of large sparse linear systems on massively parallel computers. One of its attractive features is the provision of conceptual interfaces, which provide access to hypre's solvers.

Overview

Notable features:

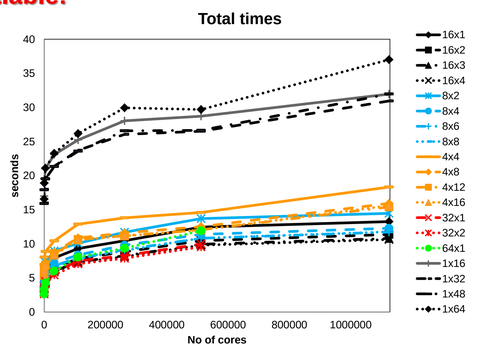
- **A variety of "conceptual" interfaces that allow users to describe their problem in a natural way**
- **Multiple interfaces are necessary to provide the most efficient solvers and data layouts**



- **State-of-the-art preconditioners and solvers, featuring structured and unstructured multigrid solvers**

Data Layouts	Solvers	System Interfaces: Struct	SStruct	FEI	IJ
Structured	Jacobi	✓	✓		
	SMG	✓	✓		
	PFMG	✓	✓		
Semi-structured	Split		✓		
	SysPFMG		✓		
	FAC		✓		
	Maxwell		✓		
Sparse matrix	ADS		✓	✓	✓
	AMS		✓	✓	✓
	BoomerAMG		✓	✓	✓
	MLI		✓	✓	✓
	ParaSails		✓	✓	✓
	Euclid		✓	✓	✓
	PILUT	✓	✓	✓	✓
Matrix free	PCG	✓	✓	✓	✓
	GMRES	✓	✓	✓	✓
	BiCGSTAB	✓	✓	✓	✓
	Hybrid	✓	✓	✓	✓

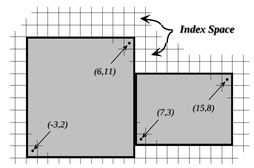
- **Easy to use and scalable!**
- **Weak scalability of AMG to more than a million cores using MPI & OpenMP**
  - **AMG-PCG**
  - **Laplace problem**
  - **Sequoia (IBM BG/Q)**
  - **MPI tasks x OpenMP threads per node**



Conceptual Interfaces

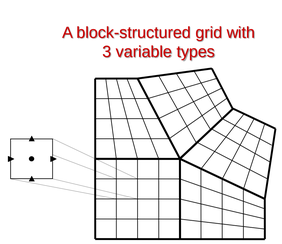
Structured Grid System Interface (Struct)

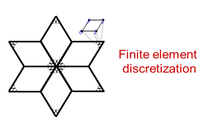
- **Appropriate for scalar problems on logically rectangular grids**
- **Describe problem via grids and stencils**

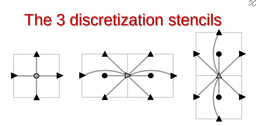


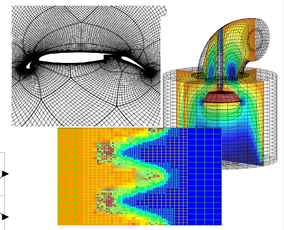
Semi-Structured Grid System Interface (SStruct)

- **Allows more general grids that are not entirely structured: block-structured grids, structured adaptive mesh refinement grids, overset grids**
- **Allows multiple variables**
- **Describe problem via multiple grids, stencils, and unstructured connections**









Linear-Algebraic System Interface (IJ)

- **Appropriate for general sparse linear systems**
- **Describe problem in terms of row and column entries**

Finite Element Interface (FEI)

- **Designed for finite element discretizations on unstructured grids**
- **Describe problem via element stiffness matrices and forcing terms**

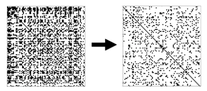
Work in Progress / Future Plans

- **Extension of the structured and semi-structured interfaces to rectangular stencil matrices for increased structure**
- **Continue efforts to get ready for exascale through reduced synchronization, investigation of use of accelerators, etc**
- **Development of a semi-structured AMG preconditioner**

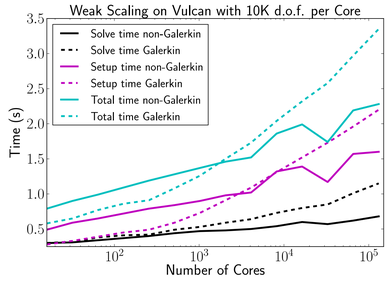
Reducing Parallel Communication Cost

Non-Galerkin AMG

- **Replaces the usual coarse-grid operators with sparser ones**

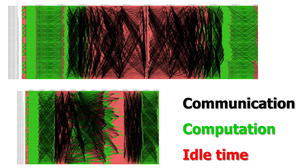


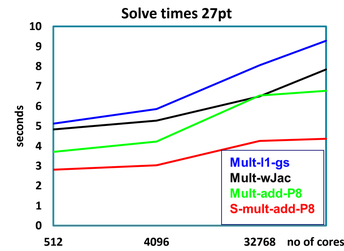
- **Speedups from 1.2x - 2.4x over existing AMG**
- **Available in *hypre* 2.10.0b**



Mult-additive AMG

- **Exploits a theoretical identity to inherit the parallelization benefits of additive and the convergence properties of multiplicative methods**
- **Improved overlapping of communication and computation**

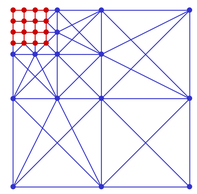




- **Speedups of up to 2x over existing AMG**
- **Available in hypre 2.10.0b**

AMG domain decomposition (AMG-DD)

- **Employs cheap global problems to speed up convergence**
- **Constructs problems algebraically from existing method**
- **Potential for FMG convergence with only log N latency!**
- **Implementing parallel code**



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More Information: http://www.fastmath-scidac.org or contact Lori Diachin, LLNL, diachin2@llnl.gov, 925-422-7130

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