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Concours CNRS IR

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Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Cursus

2010-present Post-doctoral Appointee at Sandia National Laboratories, USA
- *Extreme-scale computing group*

2006-2009 PhD. in Computer Science, University of Bordeaux I
- *CNRS doctoral fellowship (BDI)*
- *INRIA Bordeaux - Sud-Ouest. ScAlApplix project*

2003-2006 ENSEIRB, Bordeaux
- *Speciality: Parallelism, Regulation and Distributed Computation*
- *Obtained with highest honor, Valedictorian of 2006*

2006 Master of Science, University of Bordeaux I
- *Speciality: Distributed System, Network and Parallelism*
- *Obtained with highest honor*

2001-2003 Classes préparatoires aux grandes écoles

PhD. thesis

HIPS: **H**ierarchical **I**terative **P**arallel **S**olver

Goals:

- Solve $A.x = b$ by blending direct and iterative techniques.
- Build algebraic preconditioners for a Krylov method (black box).

Strategies:

- Reuse direct solver technologies (BLAS, elimination tree, symbolic factorization).
- Try to take advantage of natural parallelism of domain decomposition like methods.

Software

PhD. thesis

Hips

http://hips.gforge.inria.fr

- Languages: C / MPI
- Features: symmetric, unsymmetric (Cholesky/LU, ICC(t)/ILU(t)), real or complex systems.
- Methods: Hybrid, multistage ICC(t) and ILU(t).
- Compatible with the graph partitioners SCOTCH and METIS.
- Cecill-C license (LGPL-like licence).

Test cases

Experimental conditions:

Memory peak = Max. of fill-in peak during preconditioning.

No restart was used in GMRES.

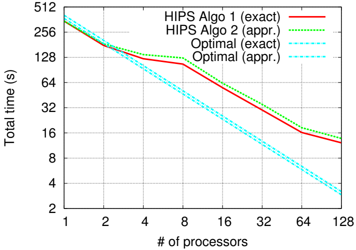
Fill-in and OPC are given for a direct method

Matrix	Type	unknowns	non-zeros	fill-in	OPC
AUDI	real sym.	943, 695	39, 297, 771	41.2	$5.4 \,.\, 10^{12}$
MHD1	real unsym.	485, 597	24, 233, 141	52.4	$9.0 \,.\, 10^{12}$
Haltere	complex sym.	1, 288, 825	10, 476, 775	38.7	$7.5 \,.\, 10^{12}$
Amande	complex sym.	6, 994, 683	58, 477, 383	53.9	$1.5 \,.\, 10^{13}$

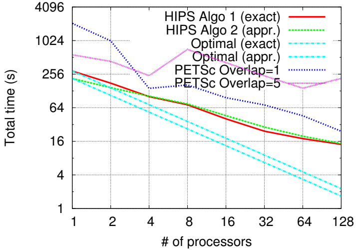
- AUDI: 3D mesh, structural mecanism (PARASOL)
- MHD1: 3D magneto-hydrodynamic
- Haltere and Amande: 3D electromagnetism problems (Helmholtz operator, CEA)

Time scalability (rel. residual norm $= 10^{-7}$)

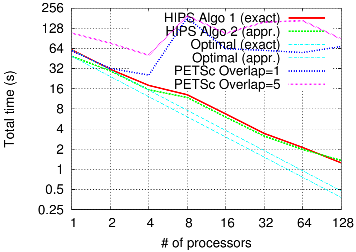
AUDI (943, 695): 181 domains



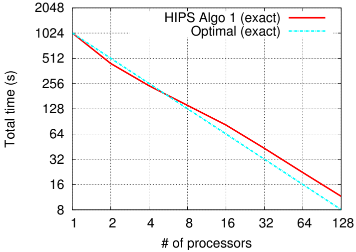
MHD1 (485, 597): 133 domains



HALTERE (1, 288, 825): 551 domains



AMANDE (6, 994, 683): 3034 domains



Teaching experience

2009-2010 ATER - ENSEIRB, Bordeaux (48 hours)

- *Introduction to Unix*
- *Grid computing and grid administration*

2007-2009 Moniteur - IUT Bordeaux I (192 hours)

- *UNIX, algorithmic basis*
- *C++ programming*
- *System programming*

Algebraic Multigrid Methods

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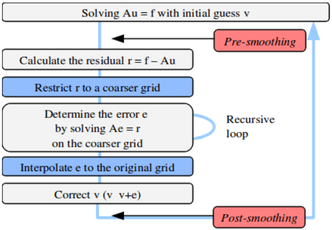
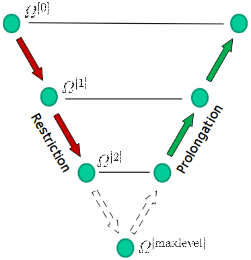
MG: capture error at multiple resolutions using grid transfer operator:

- **Smoothing** damps the oscillatory error (high energy)
- **Coarse grid correction** reduces the smooth error (low energy)

AMG: transfer operator are obtained from graph information of A

- How to construct the coarse space ?





Energy-minimizing prolongator

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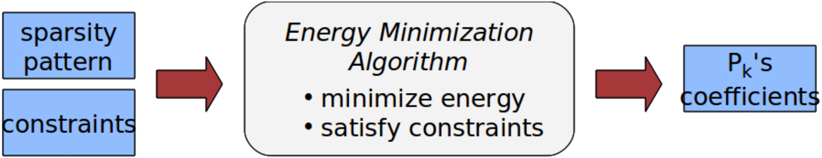
Major requirements: nullspace preservation, energy minimization, limited overlap

Idea: construct the grid transfer operator P by minimizing the energy of each column Pk while enforcing constraints (sparsity pattern and specified modes).

Input/output of energy minimization algorithm:



Results

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3D linear elasticity on a logically rectangular mesh. v

Size	SA-NR	SA-NF-NR	EMIN-NR	NSA	SA	SA-NF	EMIN
5^3	31 (1.17)	30 (1.37)	22 (1.17)	12 (1.72)	14 (1.72)	10 (2.50)	7 (1.80)
10^3	55 (1.13)	49 (1.34)	37 (1.13)	17 (1.57)	40 (1.58)	13 (2.35)	11 (1.60)
15^3	61 (1.15)	53 (1.41)	43 (1.15)	20 (1.67)	46 (1.67)	13 (2.62)	11 (1.70)
20^3	67 (1.17)	52 (1.50)	36 (1.17)	23 (1.74)	50 (1.75)	12 (3.00)	9 (1.80)
25^3	74 (1.14)	61 (1.41)	46 (1.14)	25 (1.64)	58 (1.65)	13 (2.66)	11 (1.67)
30^3	72 (1.16)	52 (1.48)	38 (1.16)	27 (1.70)	55 (1.70)	13 (2.92)	9 (1.75)
35^3	78 (1.17)	56 (1.53)	34 (1.17)	29 (1.77)	54 (1.77)	12 (3.14)	8 (1.81)
40^3	81 (1.15)	62 (1.47)	41 (1.15)	31 (1.68)	69 (1.68)	13 (2.88)	10 (1.72)

TABLE 4.5

Iteration counts and operator complexities (in parenthesis) of smoothed agregation w/o rotational modes (SA-NR), smoothed aggregation (SA) and energy minimization (EMIN) for 3D anisotropic elasticity with 10:1 mesh stretching in the x direction.

Size	SA-NR	SA-NF-NR	EMIN-NR	NSA	SA	SA-NF	EMIN
5^3	56 (1.17)	57 (1.37)	39 (1.17)	13 (1.72)	15 (1.72)	12 (2.50)	8 (1.80)
10^3	70 (1.13)	91 (1.36)	94 (1.13)	20 (1.57)	95 (1.57)	16 (2.43)	11 (1.60)
15^3	– (1.15)	98 (1.41)	88 (1.15)	25 (1.66)	81 (1.66)	18 (2.62)	12 (1.70)
20^3	98 (1.17)	96 (1.50)	79 (1.17)	28 (1.73)	91 (1.74)	18 (3.00)	9 (1.80)
25^3	87 (1.14)	99 (1.41)	96 (1.14)	30 (1.64)	91 (1.65)	19 (2.66)	11 (1.67)
30^3	92 (1.16)	97 (1.48)	83 (1.16)	33 (1.70)	96 (1.71)	18 (2.92)	9 (1.75)
35^3	99 (1.17)	94 (1.53)	82 (1.17)	35 (1.76)	89 (1.77)	18 (3.14)	9 (1.81)
40^3	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)

TABLE 4.6

Iteration counts and operator complexities (in parenthesis) of smoothed agregation w/o rotational modes (SA-NR), smoothed aggregation (SA) and energy minimization (EMIN) for 3D anisotropic elasticity with 100:1 mesh stretching in the x direction.

Software

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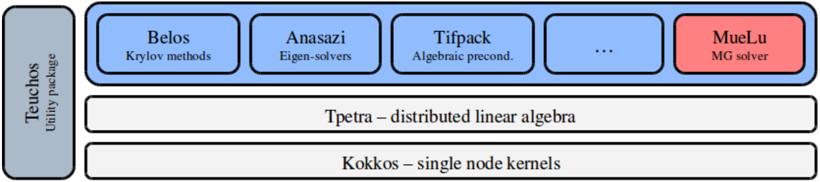
- **MueLu**: New Trilinos Multigrid Package
  - C++ - Object-oriented design
  - Massively parallel, Multicore, GPU aware
  - Templated types for 64-bit indexes, type complex, extended precision...

- Solved problems with $>$ **2.1B** of unkowns (at NERSC).

- Leverage the **Trilinos** software stack:



Jérémie Gaidamour, Jonathan J. Hu, Christopher M. Siefert and Ray S. Tuminaro. *Design Considerations for a Flexible Multigrid Preconditioning Library*. Scientific Programming, Volume 20, pages 223-239, 2012

Collaboration / Users

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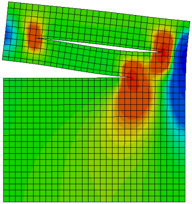
Main simulations: Structural dynamics, Computational fluid dynamics, MHD...

Ice-sheet modeling using XFEM:

- Badri Hiriyur - Aggregation maintains discontinuities on coarse levels
- Axel Gerstenberger - Fine level smoothers tailored for enriched nodes



Nonsymmetric problems: Tobias A. Wiesner

Embedded uncertainty quantification: Jonathan Hu, Eric Philipps