

Xabclib and OpenATLib Ver.1.0: A Fully Auto-tuned Sparse Iterative Library and Its Auto-tuning Interfaces

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Outline

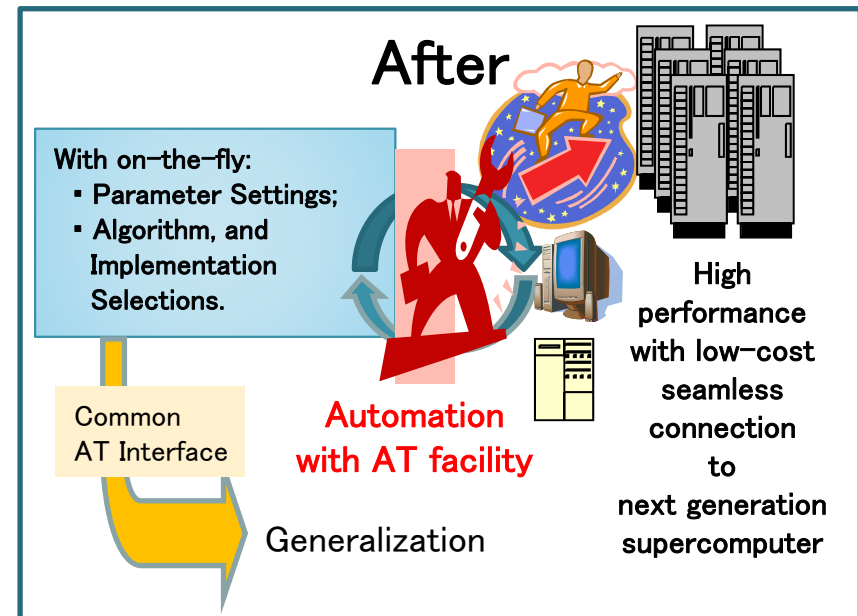
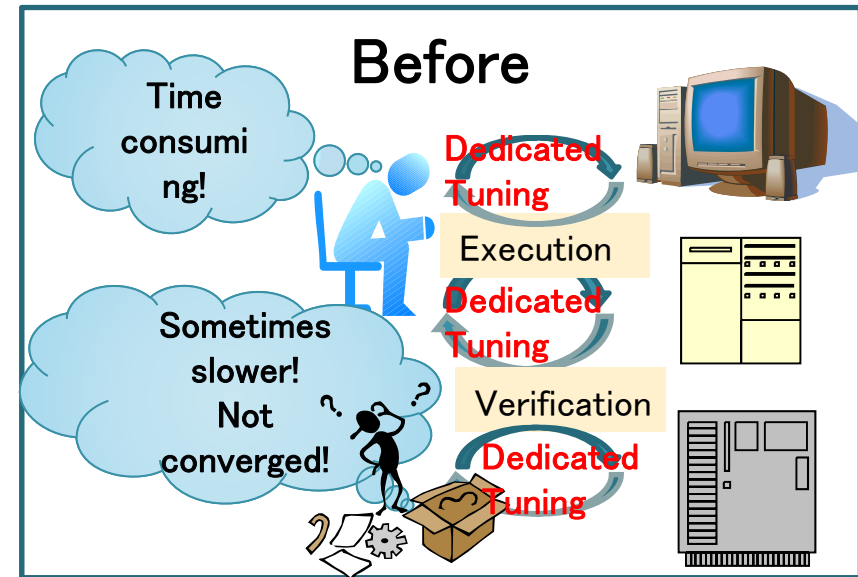
- Background
- Xabclib & OpenATLib
- Overview of New function of V.1.0
 - Automatic Selection of Numerical Algorithms and Preconditioners
- Performance Evaluation
 - The T2K Open Supercomputer (Quad core AMD Opteron)
 - Comparison with Lis and PETSc (Preliminary Results)

“Seamless and Highly-Productive Parallel Programming Environment for High-Performance Computing”, High Performance Library , MEXT, JAPAN (From 2008FY to 2011FY)

- Problem
 - Heavily relies on artisan techniques .
 - Non-productive and non-portability.
 - Time-consuming and not cost-effective.
 - Sometimes fails in convergence caused by out of ranges on parameters.

- Goal
 - To provide highly productive and performance portable numerical library.

- With respect to sparse matrix non-zero structures, we supply an *On-the-fly AT Facility for :*
 1. *Computation Kernel Selection*
 2. *Numerical Algorithm Selection*
 3. *Parallel Implementation Selection*
 4. *General AT API (OpenATLib)*



Xabclib and OpenATLib

- **Xabclib**
 - A Numerical Library with OpenATLib
 - Supplied Solvers:
 1. Linear Equations Solvers: GMRES(m), BiCGStab **by Itoh's**
 2. Eigensolvers: Restart Lanczos, **Explicit** Restart Arnoldi
- **OpenATLib**
 - A General API (Application Programming Interface) for Auto-Tuning (AT)
 1. Restart Frequency Adjustment
 2. Automatic Selection of Sparse Matrix-Vector Multiplication (SpMV) Implementations
 - Balanced Loads; Segmented Scan for Scalar Machines (BSS); Symmetric;
 3. Numerical Policy Function
 - Execution Speed; Computational Accuracy; Memory Space;
 4. Automatic Selection of Numerical Algorithms and Preconditioners
- Both are *thread* version (with OpenMP).

Xabclib :

A SPARSE ITERATIVE
SOLVER WITH AUTO-
TUNING FACILITY

(OpenMP Parallelization
Version)

OpenATLib Supplied Functions

	Function Name	Description
1	OpenATI_INIT	Set default parameters for OpenATLib and Xabclib.
2	OpenATI_DAFRT	Judge increment for restart frequency on Krylov subspace.
3	OpenATI_DSRMV	Select the best implementation for double precision symmetric SpMV with CRS format.
4	OpenATI_DURMV	Select the best implementation for double precision non-symmetric SpMV with CRS format.
5	OpenATI_DSRMV_Setup	Setup function for OpenATI_DSRMV.
6	OpenATI_DURMV_Setup	Setup function for OpenATI_DURMV.
7	OpenATI_DAFGS	Gram-Schmidt orthogonalization functions for 4 implementations.
8	OpenATI_DAFSTG	Detecting stagnation for history of residual norms.
9	OpenATI_LINEAR SOLVE	A Meta-interface of Linear Solver with numerical policy interface.
10	OpenATI_EIGEN SOLVE	A Meta-interface of Eigen Solver with numerical policy interface.

The Inner Data Structure

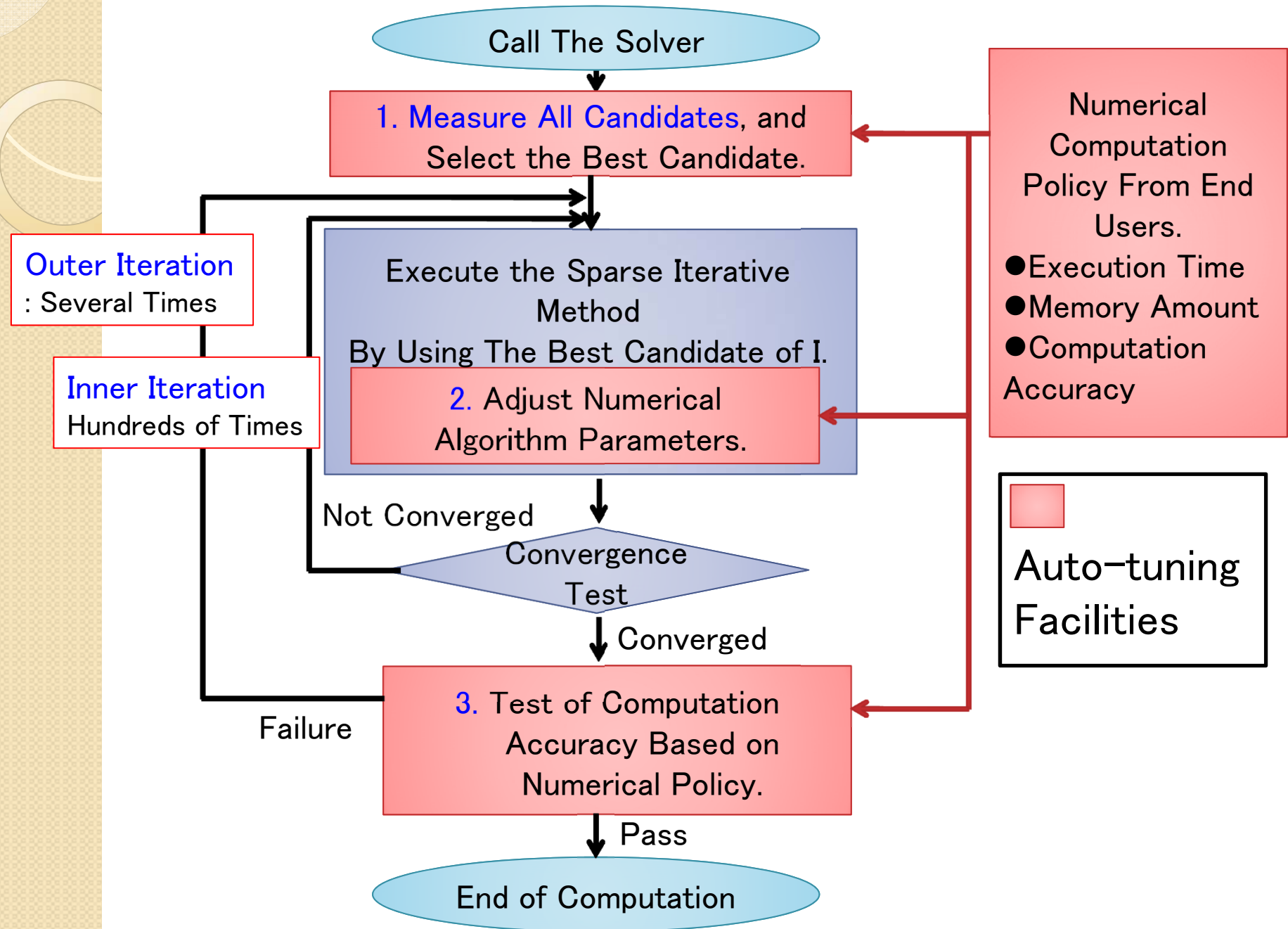
OpenAT & Xabclib thread safe parameter list

index	IATParam(50)			RATParam(50)		
	default	description	type	default	description	type
1	mandatory		M	mandatory		M
2	mandatory		M	mandatory		M
3	(*1)	[(3:20) OpenATI's Information] # of THREADS (SMP's) (*1): OMP_NUM_THREADS	I		[(3:20) OpenATI's Information] (reserved)	R
4	1	Flag of Krylov subspace expand by MM-ratio	I	100.0	threshold of MM-ratio	I
5	1	OpenATI_DSRMV auto-tuned On/Off (0:AT-off, 1:AT-on)	I		(reserved)	R
6	12	Fastest OpenATI_DSRMV impl. Method (11:block row decomp., 12:nonzero decomp., 13:parallel vector reduction)	I/O		(reserved)	R
7	1	OpenATI_DURMV auto-tuned On/Off (0:AT-off, 1:AT-on)	I		(reserved)	R
8	12	Fastest OpenATI_DURMV impl. Method (11:block row decomp., 12:nonzero decomp., 13:BSS, 21:original SS)	I/O		(reserved)	R
9	128	Columns of Segmented Scan's algorithms	I		(reserved)	R
10	2	type of Gram-Schmidt procedure (0:CGS, 1:DGKS, 2:MGs, 3:Blocked CGS)	I		(reserved)	R
11	-	DGKS refinement done or not (done : 1 , not : 0)	O		(reserved)	R
12-20		(reserved)	R		(reserved)	R
21	-	[(21:40) Xabclib's Information] # of OMP_NUM_THREADS	O	-	(reserved)	R
22	-1 (init)	Max. Iterations (if Solver recognize '-1' then set 'N')	I/O	-1(∞)	Max. elapsed time (limit time)	I
23		# of Iterations	O	1.0E-8	Convergence criterion	I
24	1	<L>preconditioner operations flag 1: not generated yet , 2 : already generated	I		(reserved)	R
25	4	<L>preconditioner type 1: None , 2 : Jacobi , 3 : SOR , 4 : ILU(0)	I	(*2)	<L>preconditioner parameter SOR(type=3): relaxation omega (1<= omega < 2) (*2)ILU(0)(type=4) : Break down threshold (default 1.0E-8)	I
26		(reserved)	R		(reserved)	R
27	20	input size of Krylov subspace (in GMRES / Arnoldi)	I		(reserved)	R
28	2	start size of Krylov subspace at subspace expand AT-on (in GMRES / Arnoldi). See IATPARAM(4)	O	-	<L> 2-norm of RHS	O
29		final size of Krylov subspace (in GMRES / Arnoldi)	O	-	2-norm of max. residual	O
30		(reserved)	R	-	floating operations (x 10^9 operations)	O
31		(reserved)	R	-	<L> preconditioner time	O
32		(reserved)	R	-	total solve time(elapsed)	O
33-49		(reserved)	R		(reserved)	R
50	0	debug info (1: on , else :off)	I		(reserved)	R

Similar to:
A Direct Sparse Solver by IBM,
WSMP:
Watson Sparse Matrix Package
<http://www-users.cs.umn.edu/~agupta/wsmp.html>

<L> : Linear system
<E> : Eigen system

The Run-time AT Strategy on OpenATLib2011





PERFORMANCE EVALUATION



COMPARISON TO OTHER LIBRARIES

Linear Algebra Libraries

- **Xablib**
 - 2011/12/29 Version 1.0 ①
- **Lis (a Library of Iterative Solvers for linear systems)**
 - 2005/09/20 Version 1.0.0
 - 2011/11/24 Version 1.2.62 ②
- **PETSc (Portable, Extensible Toolkit for Scientific Computation)**
 - 1995/06/21 Version 2.0β4
 - 2011/09/08 Version 3.2 ③

Evaluation Condition

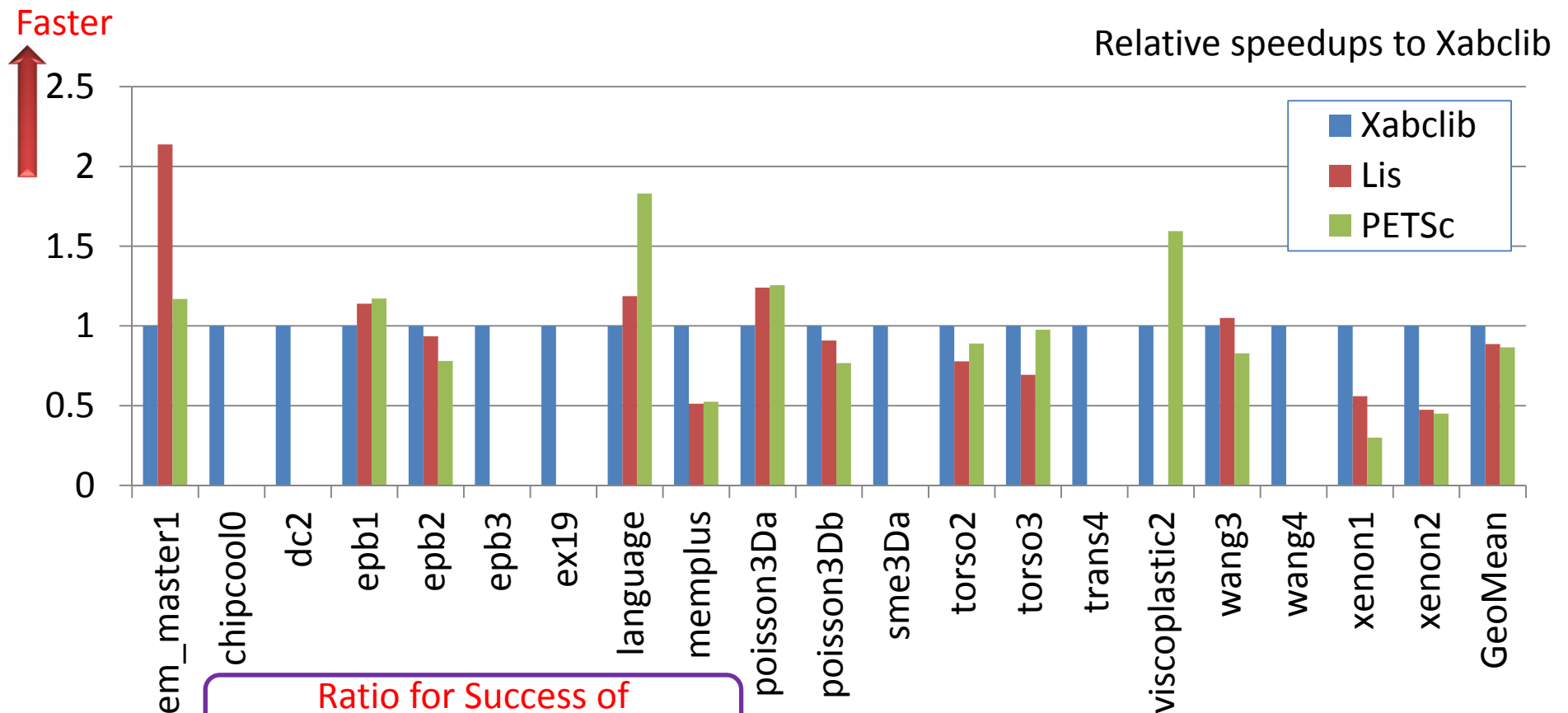
	Xabclib	Lis	PETSc
Policy	TIME	-	-
Solvers	GMRES, BiCGStab(Itoh's)	GMRES, BiCGStab	GMRES, BiCGStab
Restarts on GMRES	Auto	40 (Default)	30 (Default)
Preconditioning	None, ILU0	None (Default), ILU0	None, ILU0(Default)
Tolerance of residual	1.0D-8	1.0D-8	1.0D-8
#CPU	1, 16	1, 16	1
Time Limit	600 Sec.	600 Sec. (Force Exit)	300 Sec. (Force Exit)

Restart of GMRES is set to default value on each library.

Multi-thread version of PETSc is not under supporting now.

We only evaluate one thread execution.

GMRES, 1 Thread, No preconditioning



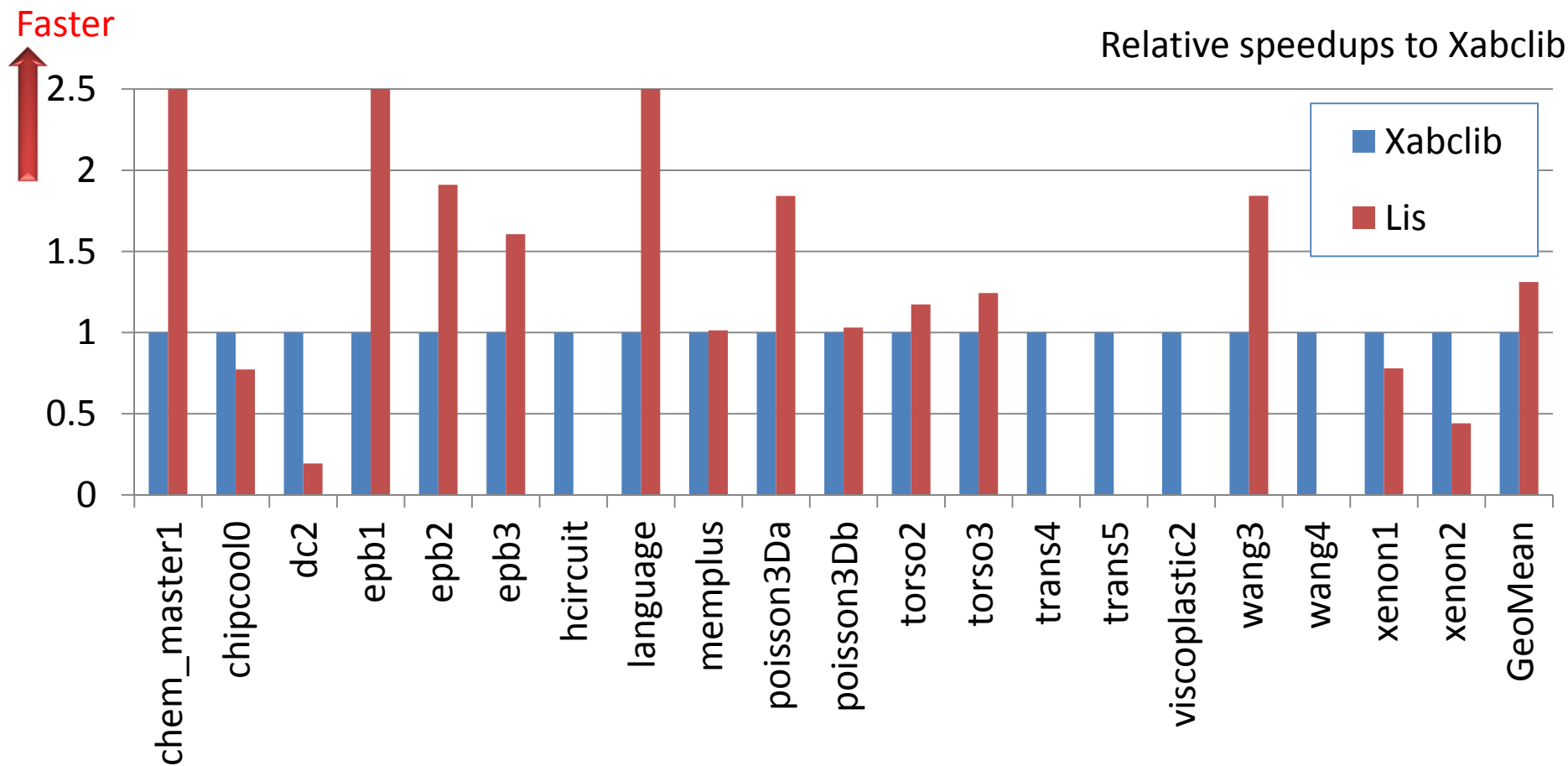
Ratio for Success of Convergence in Xabclib is 65%

	#successes	#fails
Xabclib	20	11
Lis	12	19
PETSc	13	18

Average of speedup for Lis is 0.89x.

Average of speedup for PETSc is 0.87x.

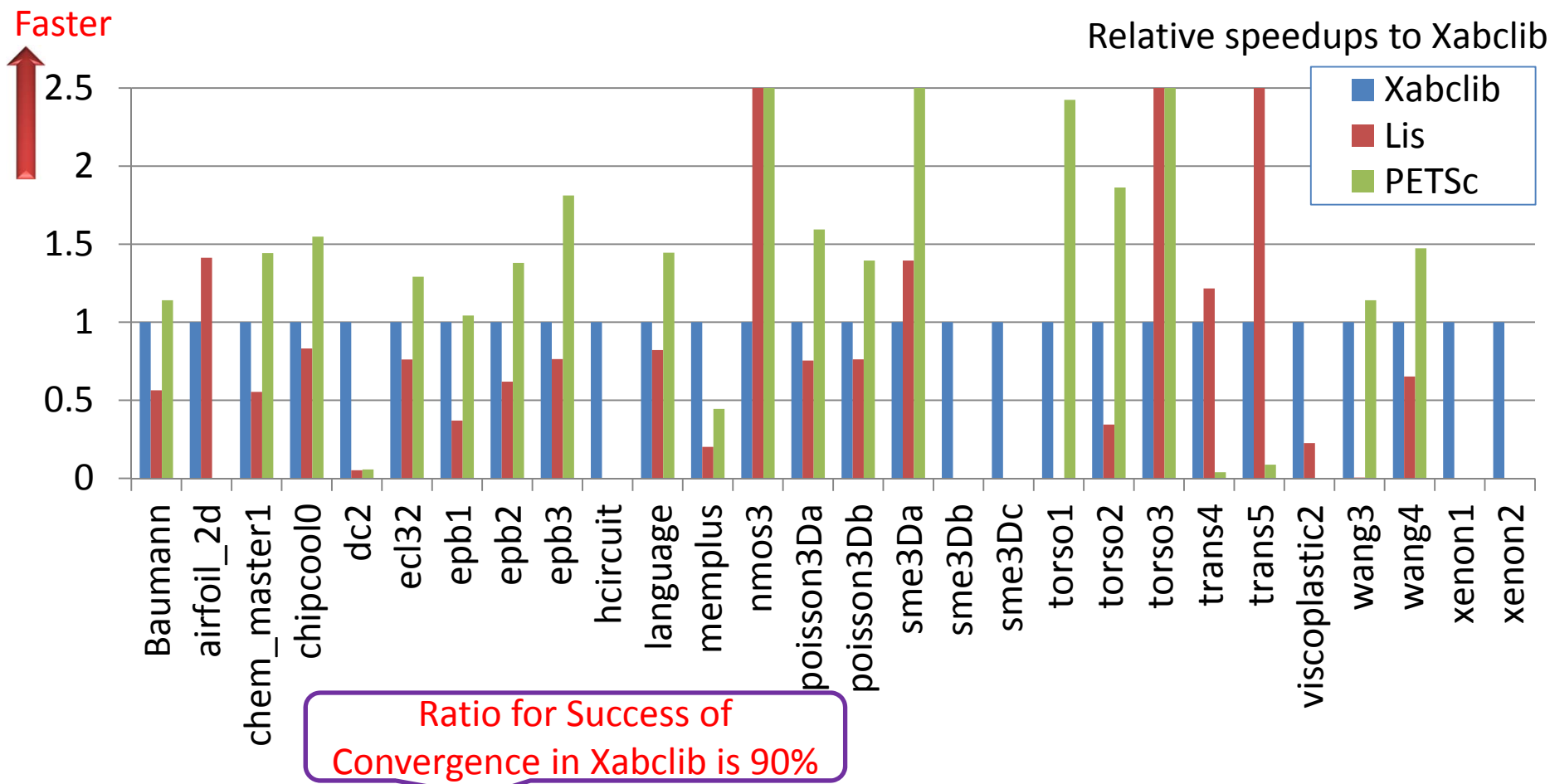
GMRES, 16 Threads, No preconditioning



	#successes	#fails
Xabclib	20	11
Lis	16	15

Average of speedup for Lis is 1.31x.

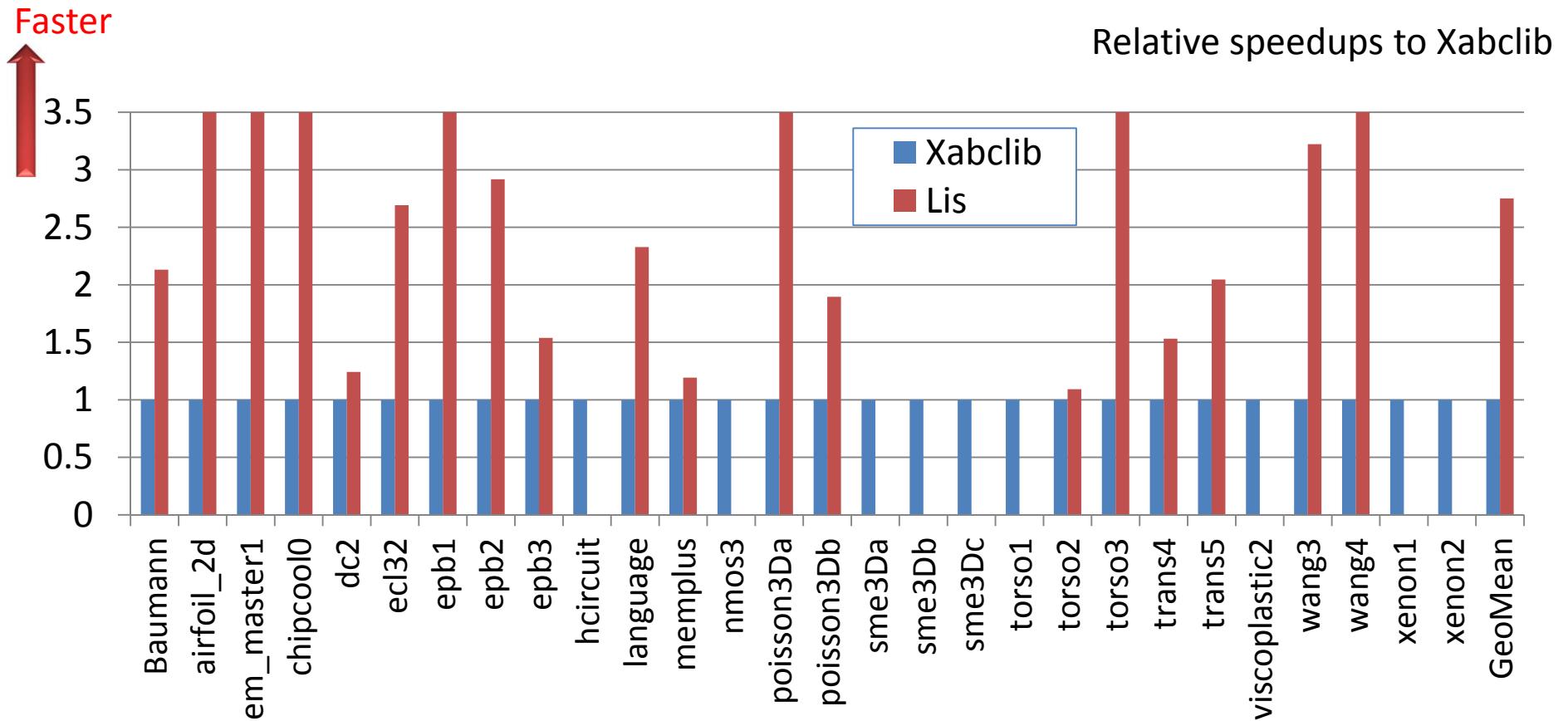
BiCGStab, 1 Thread, ILU0 Preconditioning



	#successes	#fails
Xabclib	28	3
Lis	22	9
PETSc	21	10

Average speedup for Lis is 0.65x.
 Average speedup for PETSc is 1.09x.

BiCGStab, 16Threads, ILU0 Preconditioning



Ratio for Success of Convergence in Xabclib is 90%

	#successes	#fails
Xabclib	28	3
Lis	19	12

Average speedup for Lis is 2.75x.

Conclusion

- **OpenATLib: General APIs for Auto-tuning**
 1. Algorithm Selection on Solver Level
 - OpenATI_EIGENSOLVE
 - OpenATI_LINEAR SOLVE
 2. Numerical Computation Policy
 3. **Automatic Selection of Numerical Algorithms and Preconditioners**
 - An Algorithm of Stagnation Detection at Run-time
- **Xabclib: Sparse Iterative Solver with OpenATLib**
 1. New Implementation of Numerical Algorithms
 - Itoh's Preconditioned BiCGStab
 - Explicit Restart Arnoldi with Real Vector Operation for Complex Vectors