Parallel Solutions with PETSc Solver

1st Workshop
on Nonlinear Analysis of Shell Structures

INTALES GmbH Engineering Solutions
University of Innsbruck, Faculty of Civil Engineering
University of Innsbruck, Faculty of Mathematics, Informatics and Physics

Natters/Tyrol, 15/06/2010

Outline

Starting Point

Finite element analysis

- Model data evaluation
- Load application (for nonlinear analyses: incremental)
- Equilibrium state calculation (for nonlinear analyses: repeatedly)
- Solution of systems of linear equations
- Output computation

Starting Point

Finite element analysis

- Model data evaluation
- Load application (for nonlinear analyses: incremental)
- Equilibrium state calculation (for nonlinear analyses: repeatedly)
- Solution of systems of linear equations
- Output computation

Bottlenecks

- Memory size
- Computing power
- Monolithic design of simulation software

FE Suite

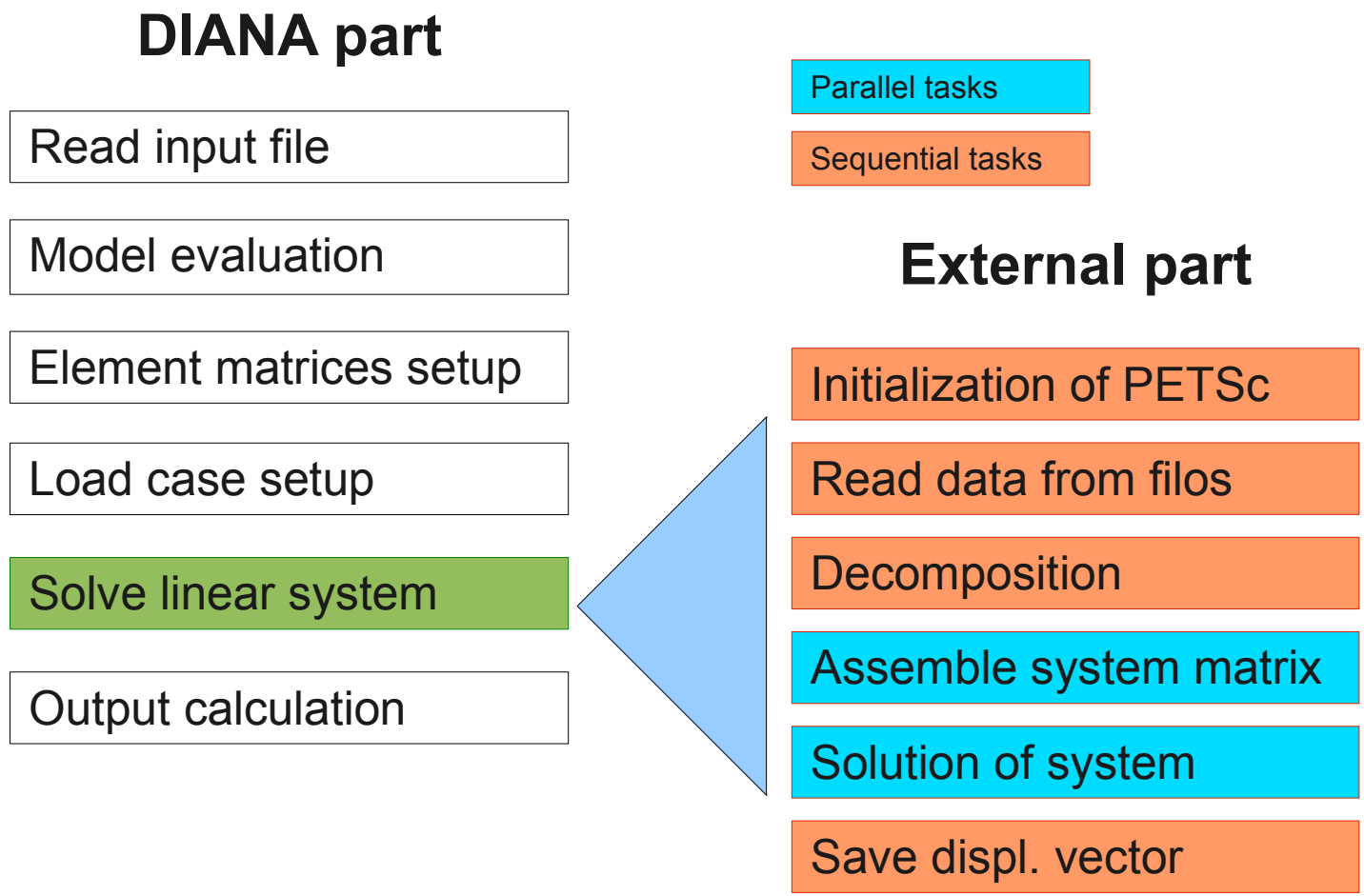
DIANA

- Developed by TNO DIANA at Delft, The Netherlands
- Offers selective insight in the source code and its modification
- Framework originating from the seventies
- Module selection and program steering not adaptive
- Sequential data structures, central FILOS database

PETSc

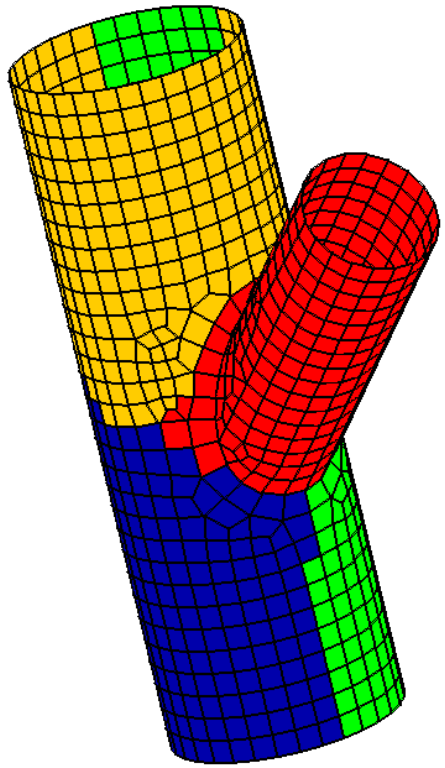
- PETSc: the portable extensible toolkit for scientific computation
- High level framework for the solution of PDE's
- Collection of libraries
- Data structures and routines for parallel computing
- Based on MPI, BLAS and LAPACK
- Open source

Development Status



The BNN Algorithm

- BNN: balancing Neumann-Neumann algorithm
- Large structure is diveded into smaller substructures
- Interface problem is solved iteratively
- Substructure problems are solved in parallel
- Coarse grid correction for global problem

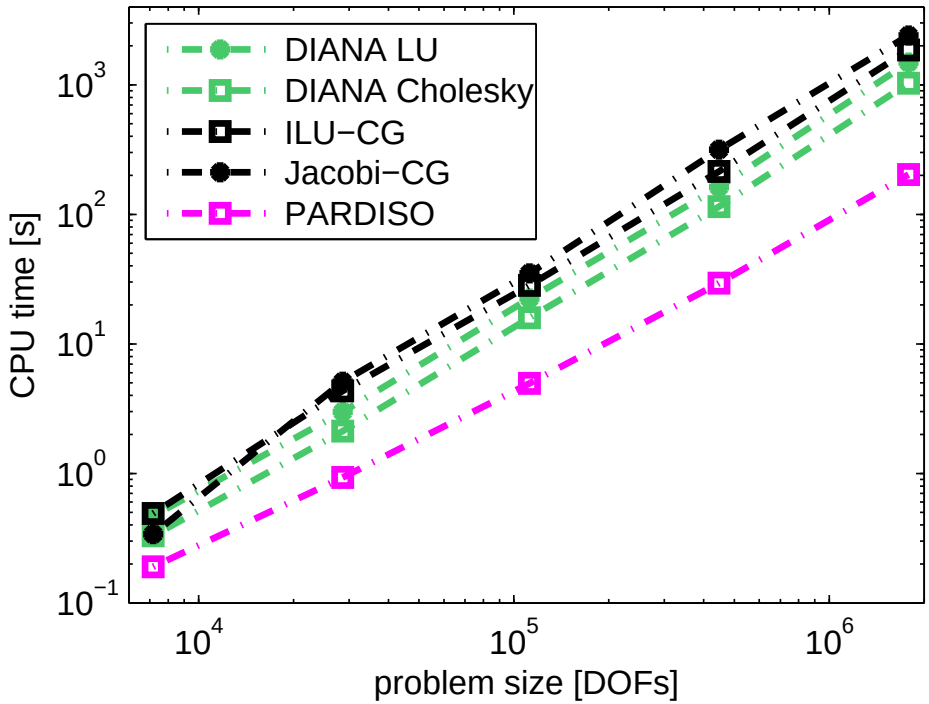


Direct Parallel Solution

MUMPS

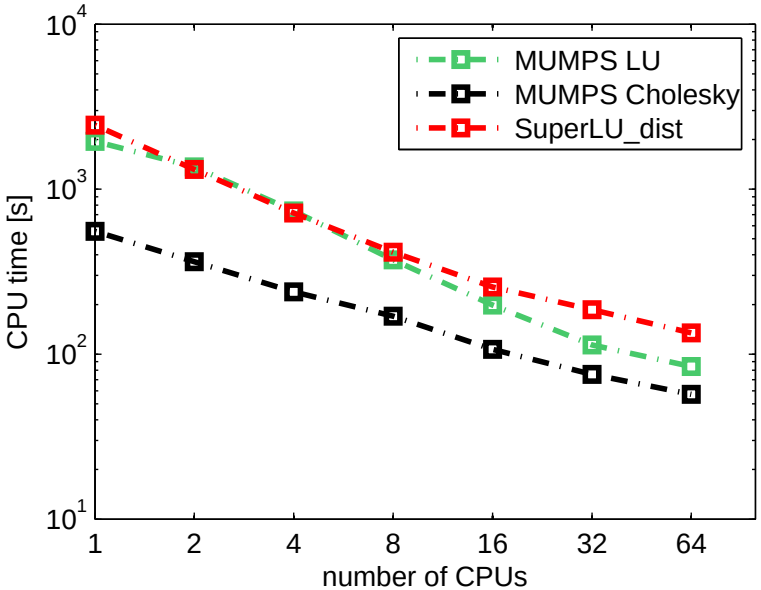
- MUMPS: multifrontal, massively parallel solver
- Relying on a similar substructuring technique as BNN
- Interface problem solved directly
- Available standalone or through PETSc
- Using MPI (message passing interface)
- Good scalability on large distributed memory systems

Benchmark Results

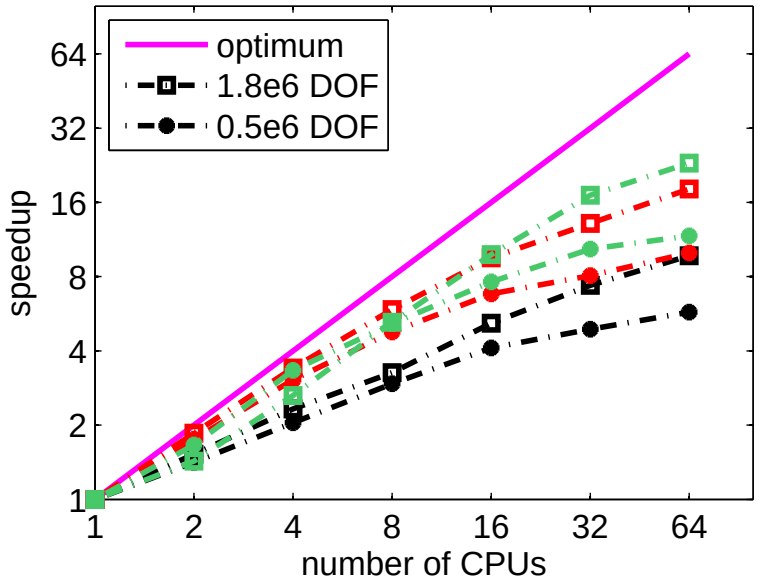


CPU time of the solving stage for the branched pipe problem, DIANA built-in solvers on `mat1` workstation

Benchmark Results



(a) Scalability with 1.8e6 DOF



(b) Speedup

Scalability and speedup on `leo2` cluster

Limitations

DIANA

- Nonlinear solution procedure inflexible
- Data handling sequential, no infrastructure for data distribution

Limitations

DIANA

- Nonlinear solution procedure inflexible
- Data handling sequential, no infrastructure for data distribution

BNN

- Not able to handle floating substructures
- Coarse grid correction poorly working for shell problems

Limitations

DIANA

- Nonlinear solution procedure inflexible
- Data handling sequential, no infrastructure for data distribution

BNN

- Not able to handle floating substructures
- Coarse grid correction poorly working for shell problems

MUMPS

- Large memory requirement
- Black box solver not regarding problem structure

Outlook

Future possibilities

- Extend PETSc BNN to work efficiently for shell problems
- Use PETSc SNES context for solution of nonlinear problems
- Independent development of FE-code for flexible and efficient implementation

References

Andreas Grassl.
Domain Decomposition in DIANA.
Master thesis, Faculty of Mathematics, Computer Science and Physics of the University of Innsbruck, 2010.

Jonna Manie and Wijtze P. Kikstra.
Analysis Procedures.
DIANA - Finite Element Analysis User's Manual release 9.3. TNO DIANA BV, Delft, 1 edition, April 2008.

Satish Balay, Kris Buschelman, William D. Gropp, Dinesh Kaushik, Matthew G. Knepley, Lois Curfman McInnes, Barry F. Smith, and Hong Zhang.
PETSc web page.
`http://www.mcs.anl.gov/petsc`, February 2010.
Date retrieved: February 18, 2010.

Iain S. Duff, Albert M. Erisman, and John K. Reid.
Direct Methods for Sparse Matrices.
Monographs on numerical analysis. Oxford Science Publications, New York, 2 edition, 1989.

Yousef Saad.
Iterative Methods for Sparse Linear Systems.
SIAM, Minneapolis, 2 edition, 2003.

Andrea Toselli and Olof B. Widlund.
Domain Decomposition Methods - Algorithms and Theory.
Springer, Berlin Heidelberg New York, 2004.