Development of a Numerical Library based on Hierarchical Domain Decomposition for Post Petascale Simulation

ADVENTURE System – Easy to Run Faster with Large Data On Post-Petascale Supercomputers

Overview

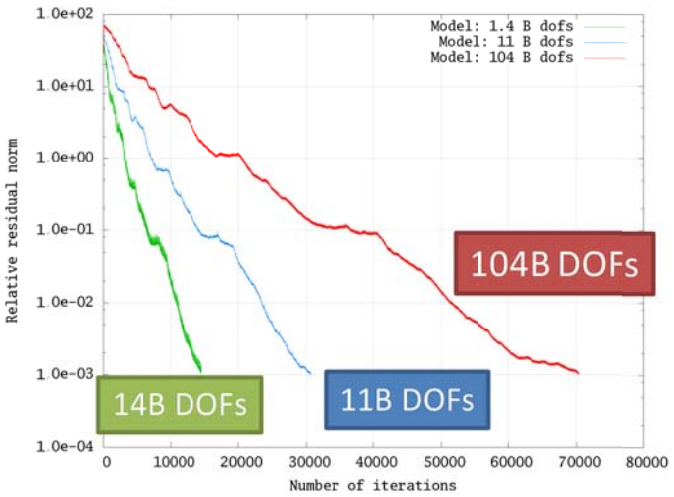
We have been developing an open source system software called **ADVENTURE** system. The ADVENTURE system is a general-purpose parallel finite element analysis system and can simulate a large scale analysis model with supercomputer like the Earth Simulator or K-computer. In the ADVENTURE system, HDDM (hierarchical domain decomposition method), a very effective technique for large-scale analysis, was developed.

Our aim in this project is to develop a **numerical library** based on HDDM that is extended to pre and post processing parts, including mesh generation and visualization of large scale data, for the Post Petascale simulation.

In this project, **LexADV**, an open source software library, is developed for the extreme-scale numerical simulations in continuum mechanics.

DDM Iterative Solver (LexADV_TryDDM)

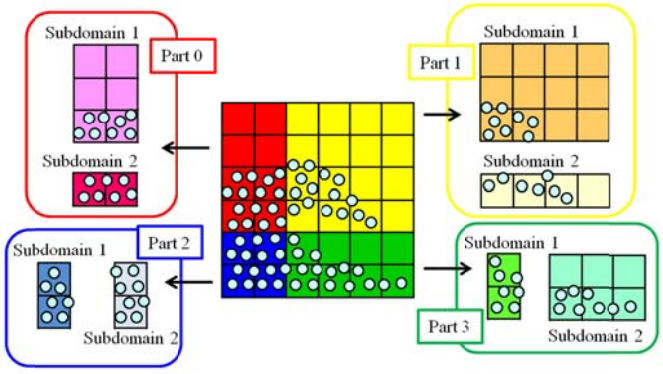
- Linear solver for Schur complement (condensed) system
- Fast and stable convergence by using a Scaled-BDD method
- High parallel efficiency by 2-level domain decomposition



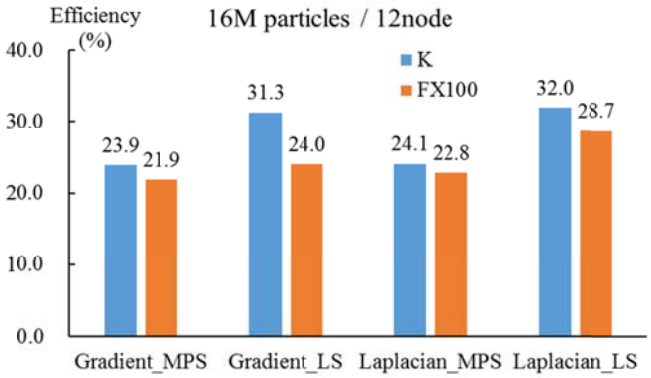
Convergence histories in solving the Schur complement equation [Ogino & Shioya, COMPSAFE '14]

Parallel Framework for Particle Simulations (LexADV_EMPS)

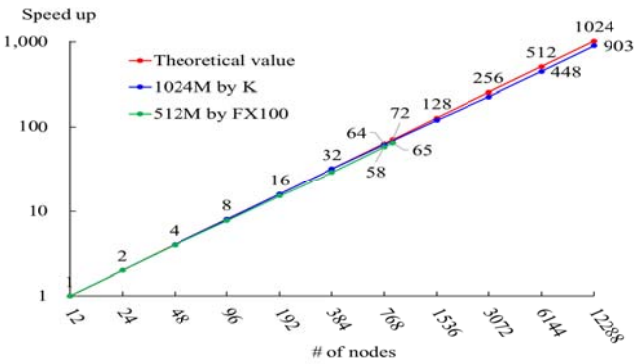
- Bucket-based domain decomposition
- Dynamic load balancing
- Halo exchange pattern generation for communication



Two-level domain decomposition based on the bucket [DOI: 10.15748/jasse.1.16]



Efficiency of K computer and FX100 for gradient and Laplacian operators



Strong scaling by K computer and FX100.

CREST
Core Research for Evolutionary Science and Technology

Development of System Software Technologies for post-Peta Scale High Performance Computing

"**LexADV**" Software: LexADV is a free, open-source software for large-scale numerical simulations of continuum mechanics problems.

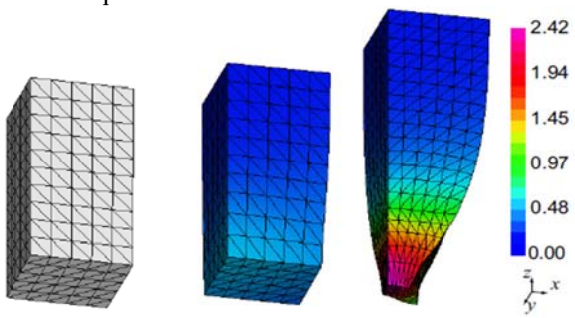
Platforms supported: Linux, Mac OS X, Windows (Cygwin)

Web site : http://adventure.sys.t.u-tokyo.ac.jp/lexadv/ (LexADV Library)
http://adventure.sys.t.u-tokyo.ac.jp/ (ADVENTURE System)

Name	Latest Version	Language	Description
LexADV_AutoMT	0.1b	C	Matrix and tensor operation library
LexADV_Metis	Coming Soon!	C, MPI	Hierarchical domain decomposition and mesh subdivision tool
LexADV_IsDDM	Coming Soon!	C, MPI	DDM-based linear equation solver library
LexADV_TryDDM	0.1b	C, MPI	DDM-based solver library based on explicit static condensation
LexADV_EMPS	0.1.2b	C, MPI	Explicit MPS solver framework
LexADV_VSCG	0.2b	C	Ultra-high-resolution scientific visualization library
LexADV_WOVis	0.4b	C, MPI	Parallel offline surface rendering tool w/ VSCG

DSL for Continuum Mechanics (LexADV_AutoMT)

- Convenient tool to program vector/matrix/tensor operations
- LaTeX equation conversion to C/Fortran code



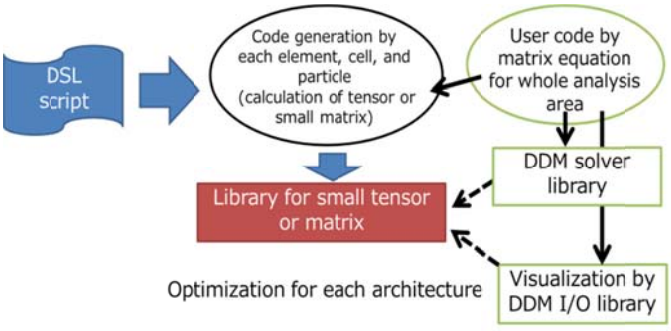
A necking problem

$$d\bar{\varepsilon}^p = \frac{\sigma' : C^e : d\varepsilon}{2\bar{\sigma}(G + \frac{1}{3}\frac{d\bar{\sigma}}{d\bar{\varepsilon}^p})}$$

LaTeX equation of stress integration

```
AutoMT_colon_mnst4_st_st(C, Strain_Increment, tmp_st_1);
AutoMT_colon_st_st_s(Deviatoric_Stress, tmp_st_1, &tmp_s_1);
AutoMT_colon_st_st_s(Deviatoric_Stress, Deviatoric_Stress, &tmp_s_2);
Equivalent_Stress = sqrt(tmp_s_2 * 3.0 / 2.0);
tmp_s_2 = 2.0 * (G + Hardening_Ratio / 3.0) * Equivalent_Stress;
Equivalent_Plastic_Strain_Increment = tmp_s_1 / tmp_s_2;
```

Generated C code

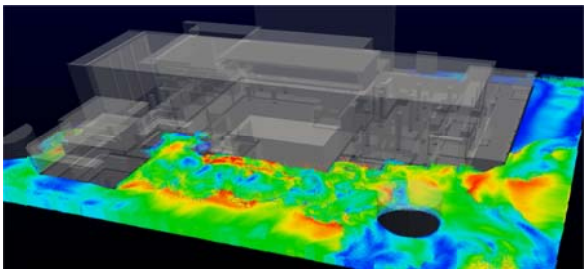


[DOI: 10.1299/mel.15-00349]

Examples of Numerical Simulation

Tsunami running-up and inundated simulation for Fukushima Daiichi Nuclear Power Station—using explicit MPS method and dynamically load balancing technique.

Photo-realistic visualization of tsunami running up analysis by using the explicit MPS method. The number of particles is about 250 million, and the analysis time is 1,800 seconds.



Results of tsunami inundated analysis for the interior of the turbine building by using the explicit MPS method.

[SC14, SC15, SC16, SC17 research poster]

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JST Japan Science and Technology Agency