Challenges towards Post-Peta/Exascale Computing
Information Technology Center
The University of Tokyo

Kengo Nakajima
Information Technology Center
The University of Tokyo

53rd HPC User Forum, RIKEN AICS, Kobe, Japan
July 16, 2014
Information Technology Center
The University of Tokyo
(ITC/U.Tokyo)

- Campus/Nation-wide Services on Infrastructure for Information, related Research & Education
- Established in 1999
  - Campus-wide Communication & Computation Division
  - Digital Library/Academic Information Science Division
  - Network Division
  - Supercomputing Division
- Core Institute of Nation-wide Infrastructure Services/Collaborative Research Projects
  - Joint Usage/Research Center for Interdisciplinary Large-scale Information Infrastructures (JHPCN) (2010-)
  - HPCI (HPC Infrastructure)
Innovative High Performance Computing Infrastructure (HPCI)

- HPCI Consortium
  - Providing proposals/suggestions to the government and related organizations, operations of infrastructure
  - 38 organizations (Computer Centers, Users)
  - Operations started in Fall 2012
    - https://www.hpci-office.jp/

- Missions
  - Infrastructure (Supercomputers & Distributed Shared Storage System)
    - Seamless access to K, SC’s (9 Univ’s), & user's machines
  - Promotion of Computational Science
    - Strategic Programs for Innovative Research (SPIRE)
  - R&D for Future Systems (Post-peta/Exascale)
AICS, RIKEN: K computer (11.28 PF, 1.27PiB)

Osaka Univ.: SX-9 (16TF, 10TB)
SX-8R (5.3TF, 3.3TB)
PCCluster (22.7 TF, 4.6TB)

Kyushu Univ.: FX10 (181.16TF, 24TB)
CX400 (811.9TF, 184.5TB)
HA8000-tc (712.5TF, 24.7TB)
SR16000 VM1 (8.19TF, 16TB)

Nagoya Univ.: FX10 (90.8TF, 12TB)
CX400 (471TF, 43TB)

Tokyo Institute of Technology:
TSUBAME2.5 (5.79 PF, 150TB)

Hokkaido Univ.: SR16000/M1 (172TF, 22TB)
BS2000 (44TF, 14TB)

Tohoku Univ.: SX-9 (29.4TF, 18TB)
Express5800 (1.74TF), 3TB

Univ. of Tsukuba: T2K (95.4Tflops, 20TB)
HA-PACS (802Tflops, 34.3TB)
FIRST (36.1TFlops, 1.6TB)

Kyoto Univ.: XE6 (300.8 TF, 59 TB)
GreenBlade8000 (242.5TF, 38TB)
2548X (10.6TF, 24TB)

Univ. of Tokyo: FX10 (1.13PF, 150TB)
SR16000/M1 (54.9TF, 10.94TB)
T2K (75.36TF, 16TB, 31.25TB)
EastHubPCCluster (10TF, 5.71TB, 13TF, 8.125TB)
GPU Cluster (CPU 4.5TF, GPU 16.48TF, 1.25TB)
WestHubPCCluster (12.37TF, 8.25TB)
RENKEI-VPE: VM Hosting

Tokyo Institute of Technology:
TSUBAME2.5 (5.79 PF, 150TB)
9 supercomputer centers located at universities in Japan

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</thead>
<tbody>
<tr>
<td><strong>Hokkaido</strong></td>
<td>Hitachi SR16000/M1 (172 TF, 22TB) Cloud System Hitachi BS2000 (44TF, 14TB)</td>
<td>10+ PF</td>
<td>50+ PF</td>
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<tr>
<td><strong>Tohoku</strong></td>
<td>NEC SX-9 + Exp5800 (31TF)</td>
<td>~1PFlop/s</td>
<td>30+PFlop/s</td>
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<td><strong>Tsukuba</strong></td>
<td>HA-PACS (800 TF) (Manycore system) (700+ TF)</td>
<td>PostT2K (20+ PF, (100+ TiB, 600TiB, 4.0+ PB/s, 0.68+ PB/s))</td>
<td>100+ PF</td>
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<td><strong>Tokyo</strong></td>
<td>Fujitsu FX10 (1PFlops, 150TiB, 408 TB/s), Hitachi SR16000/M1 (54.9 TF, 10.9 TiB, 5.376 TB/s)</td>
<td>50+ PF</td>
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<tr>
<td><strong>Tokyo Tech.</strong></td>
<td>Tsubame 2.0 (2.4PF, 97TB, 744 TB/s) Tsubame 2.5 (5.5+ PF, 110+ TB, 1160 TB/s)</td>
<td>Tsubame 3.0 (20+ PF) Tsubame 4.0 (100+ PF)</td>
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<td><strong>Nagoya</strong></td>
<td>Fujitsu M9000(3.8TF, 1TB/s), HX600(25.6TF, 6.6TB/s) FX1(30.7TF, 30 TB/s)</td>
<td>50+ PFlops</td>
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<td><strong>Kyoto</strong></td>
<td>Cray XE6 (300TF, 92.6TB/s), GreenBlade 8000 (243TF, 61.5 TB/s)</td>
<td>Cray XC30 (400TF) 600TF</td>
<td>10+ PF</td>
<td>50+ PF</td>
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<td><strong>Osaka</strong></td>
<td>SX-8 + SX-9 (21.7 TF, 3.3 TB, 50.4 TB/s)</td>
<td>(500+ TiB/s)</td>
<td>(5+ PiB/s)</td>
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<tr>
<td><strong>Kyushu</strong></td>
<td>Hitachi SR16000(25TF)</td>
<td>Hitachi HA80000th210(500TF, 215 TiB, 98.82TiB/s), Xeon Phi (212TF, 26.25 TiB, 67.2 TB/s), SR16000(8.2TF, 6 TiB, 4.4 TB/s)</td>
<td>10+ PF</td>
<td>50+ PF</td>
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Supercomputing Division of ITC/U.Tokyo (SCD/ITC/UT)
http://www.cc.u-tokyo.ac.jp

• Services & Operations of Supercomputer Systems, Research, Education

• History
    • Oldest Academic Supercomputer Center in Japan
    • Nation-Wide, Joint-Use Facility: Users are not limited to researchers and students of U.Tokyo
  – Information Technology Center (1999~) (4 divisions)

• 12 Faculty Members
  – System Software, Numerical Library, Applications, GPU
Research Activities

• Collaboration with Users
  – Linear Solvers, Parallel Vis., Performance Tuning

• Research Projects
  – FP3C (collab. with French Institutes) (FY.2010-2013)
    • Tsukuba, Tokyo Tech, Kyoto
    • 1 of 4 Teams: General Purpose Processors, Latency Cores
    • Fujitsu
  – ppOpen-HPC (FY.2011-)

• International Collaboration
  – Lawrence Berkeley National Laboratory (USA)
  – National Taiwan University (Taiwan)
  – Intel Parallel Computing Center
ICT/U.Tokyo joined IPCC in Dec. 2013 officially announced in June 2014 focusing on optimization of FEM/ICCG solver on Xeon/Phi
• Supercomputer Systems in SCD/ITC/UT
• Post T2K System, ppOpen-HPC
Current Supercomputer Systems
University of Tokyo

- Total number of users ~ 2,000 (50% from outside of UT)
- Hitachi HA8000 Cluster System (T2K/Tokyo) (2008.6-2014.3)
  - Cluster based on AMD Quad-Core Opteron (Barcelona)
  - 140.1 TFLOPS
- Hitachi SR16000/M1 (Yayoi) (2011.10-)
  - Power 7 based SMP with 200 GB/node
  - 54.9 TFLOPS
- Fujitsu PRIMEHPC FX10 (Oakleaf-FX) (2012.04-)
  - SPARC64 IXfx
  - Commercial version of K computer
  - 1.13 PFLOPS (1.043 PFLOPS for LINPACK, 36th in 43rd TOP500)
  - Additional 576 Nodes with 136 TF (Oakbridge-FX, 2014.04-)
### Supercomputers at ITC, U. of Tokyo

(redirected, March 2014)

<table>
<thead>
<tr>
<th>System</th>
<th>Peak Performance</th>
<th>Number of Nodes</th>
<th>Memory</th>
<th>Peak Performance per Node</th>
<th>Memory per Node</th>
<th>Disk Capacity</th>
<th>CPU Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oakleaf-fx</td>
<td>1.13 PFLOPS</td>
<td>4800</td>
<td>32 GB</td>
<td>236.5 GFLOPS</td>
<td>32 GB</td>
<td>1 PB + 2.1 PB</td>
<td>SPARC64 lfx 1.84GHz</td>
</tr>
<tr>
<td>T2K-Todai</td>
<td>140 TFLOPS</td>
<td>952</td>
<td>32000 GB</td>
<td>147.2 GFLOPS</td>
<td>128 GB</td>
<td>1 PB</td>
<td>AMD Quad Core Opteron 2.3GHz</td>
</tr>
<tr>
<td>Yayoi</td>
<td>54.9 TFLOPS</td>
<td>56</td>
<td>11200 GB</td>
<td>980.48 GFLOPS</td>
<td>200 GB</td>
<td>556 TB</td>
<td>IBM POWER 7 3.83GHz</td>
</tr>
</tbody>
</table>

“Oakbridge-fx” with 576 nodes installed in April 2014 (separated) (136TF)

**Total Users > 2,000**
Supercomputers in U.Tokyo
2 big systems, 6 yr. cycle

<table>
<thead>
<tr>
<th>Year</th>
<th>System</th>
<th>Type</th>
<th>Performance</th>
<th>Memory</th>
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<tbody>
<tr>
<td>FY05</td>
<td>Hitachi SR11000/J2</td>
<td>Fat nodes</td>
<td>18.8 TFLOPS</td>
<td>16.4 TB</td>
</tr>
<tr>
<td>FY06</td>
<td>Hitachi SR16000/M1</td>
<td>Our last SMP</td>
<td>based on IBM Power-7</td>
<td>54.9 TFLOPS</td>
</tr>
<tr>
<td>FY07</td>
<td>Hitachi HA8000 (T2K)</td>
<td>(Flat) MPI</td>
<td>140 TFLOPS</td>
<td>31.3 TB</td>
</tr>
<tr>
<td>FY08</td>
<td>Fujitsu PRIMEHPC FX10</td>
<td>Turning point</td>
<td>based on SPARC64 IXfx</td>
<td>1.13 PFLOPS</td>
</tr>
<tr>
<td>FY09</td>
<td>Post T2K</td>
<td></td>
<td>O(10^1-10^2) PFLOPS</td>
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Peta 京 (=K) Exa
Features of FX10 (Oakleaf-FX)

• Well-Balanced System
  – Peak Performance: 1.13 PFLOPS, 398 TB/sec
  – Max. Power Consumption < 1.40 MW (<2.00MW with A/C)
    • Strict Requirement after March 11, 2011
    • 1.043 PFLOPS for Linpack with 1.177 MW (excluding A/C)

• 6-Dim. Mesh/Torus Interconnect
  – Highly Scalable Tofu Interconnect
  – 5.0x2 GB/sec/link, 6 TB/sec for Bi-Section Bandwidth

• High-Performance File System
  – FEFS (Fujitsu Exabyte File System) based on Lustre

• Flexible Switching between Full/Partial Operation
• K compatible (16 cores/node, K: 8 cores/node) !
• Open-Source Libraries/Applications
• Highly Scalable for both of Flat MPI and Hybrid (OpenMP + MPI)
• Aggregate memory bandwidth: 398 TB/sec.
• Local file system for staging with 1.1 PB of capacity and 131 GB/sec of aggregate I/O performance (for staging)
• Shared file system for storing data with 2.1 PB and 136 GB/sec.
• External file system: 3.6 PB
# SPARC64™ IXfx

<table>
<thead>
<tr>
<th>CPU</th>
<th>SPARC64™ IXfx 1.848 GHz</th>
<th>SPARC64™ VIIIfx 2.000 GHz</th>
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</thead>
<tbody>
<tr>
<td>Number of Cores/Node</td>
<td>16</td>
<td>8</td>
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<tr>
<td>Size of L2 Cache/Node</td>
<td>12 MB</td>
<td>6 MB</td>
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<tr>
<td>Peak Performance/Node</td>
<td>236.5 GFLOPS</td>
<td>128.0 GFLOPS</td>
</tr>
<tr>
<td>Memory/Node</td>
<td>32 GB</td>
<td>16 GB</td>
</tr>
<tr>
<td>Memory Bandwidth/Node</td>
<td>85 GB/sec (DDR3-1333)</td>
<td>64 GB/sec (DDR3-1000)</td>
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<tr>
<td>Software of FX10</td>
<td></td>
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<tr>
<td><strong>Computing/Interactive Nodes</strong></td>
<td><strong>Login Nodes</strong></td>
<td></td>
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<tr>
<td><strong>OS</strong></td>
<td>Special OS (XTCOS)</td>
<td>Red Hat Enterprise Linux</td>
</tr>
<tr>
<td><strong>Compiler</strong></td>
<td>Fujitsu Fortran 77/90 C/C++ GNU GCC, g95</td>
<td>Fujitsu (Cross Compiler) Fortran 77/90 C/C++ GNU (Cross Compiler) GCC, g95</td>
</tr>
<tr>
<td><strong>Library</strong></td>
<td>Fujitsu SSL II (Scientific Subroutine Library II), C-SSL II, SSL II/MPI Open Source BLAS, LAPACK, ScaLAPACK, FFTW, SuperLU, PETSc, METIS, SuperLU_DIST, Parallel NetCDF</td>
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<tr>
<td><strong>Applications</strong></td>
<td>OpenFOAM, ABINIT-MP, PHASE, FrontFlow/blue FrontSTR, REVOCAP</td>
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<tr>
<td><strong>File System</strong></td>
<td>FEFS (based on Lustre)</td>
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<tr>
<td><strong>Free Software</strong></td>
<td>bash, tcsh, zsh, emacs, autoconf, automake, bzip2, cvs, gawk, gmake, gzip, make, less, sed, tar, vim etc.</td>
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<tr>
<td><strong>NO ISV/Commercial Applications (e.g. NASTRAN, ABAQUS, STAR-CD etc.)</strong></td>
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History of Work Ratio
Research Area based on CPU Hours FX10 in FY.2013 (2013.4~2014.3E)
Simulation of Geologic CO$_2$ Storage

[Dr. Hajime Yamamoto, Taisei]
Multi-Scale/Physics Heart Simulator (UT Heart)
Prof. T. Hisada (U.Tokyo) et al., SC10

[Hisada-Sugiura Lab., U.Tokyo]
Services for Industry (FX10)

- Originally, only academic users have been allowed to access our supercomputer systems.
- Since FY.2008, we started services for industry
  - supports to start large-scale computing for future business
  - not compete with private data centers, cloud services …
  - basically, results must be open to public
  - max 10% total comp. resource is open for usage by industry
  - special qualification processes/special (higher) fee for usage
- Currently Oakleaf-FX is open for industry
  - Normal usage (more expensive than academic users)
    - 4 groups (FY.2014) (1 IT, 3 manufacturing), fundamental research
  - Trial usage with discount rate
  - Research collaboration with academic rate (e.g. Taisei)
  - Open-Source/In-House Codes (NO ISV/Commercial App.)
Training & Education (FX10)

• 2-Day “Hands-on” Tutorials for Parallel Programming by Faculty Members of SCD/ITC (Free)
  – Fundamental MPI (3 times per year)
  – Advanced MPI (2 times per year)
  – OpenMP for Multicore Architectures (2 times per year)
  – Participants from industry are accepted.

• Graduate/Undergraduate Classes with Supercomputer System (Free)
  – We encourage faculty members to introduce hands-on tutorial of supercomputer system into graduate/undergraduate classes.
  – Up to 12 nodes (192 cores) of Oakleaf-FX
  – Proposal-based
  – Not limited to Classes of the University of Tokyo, 2-3 of 10

• RIKEN AICS Summer/Spring School (2011~)
• Supercomputer Systems in SCD/ITC/UT
• Post T2K System, ppOpen-HPC
Post T2K System

- 20-30 PFLOPS, FY.2015
- Many-core based (e.g. (only) Intel MIC/Xeon Phi)
- Joint Center for Advanced High Performance Computing (JCAHPC, http://jcahpc.jp/)
  - University of Tsukuba
  - University of Tokyo
  - New system will installed in Kashiwa-no-Ha (Leaf of Oak) Campus/U.Tokyo, which is between Tokyo and Tsukuba
Post T2K System

• 20-30 PFLOPS, FY.2015
• Many-core based (e.g. (only) Intel MIC/Xeon Phi)
• Joint Center for Advanced High Performance Computing (JCAHPC, http://jcahpc.jp/)
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• Programming is still difficult, although Intel compiler works.
  – (MPI + OpenMP) + Y
  – Tuning for performance (e.g. prefetching) is essential
  – Some framework for helping users needed
Key-Issues for Appl’s/Algorithms towards Post-Peta & Exa Computing
Jack Dongarra (ORNL/U. Tennessee) at ISC 2013

- Heterogeneous/Hybrid Architecture
- Communication/Synchronization Reducing Algorithms
- Mixed Precision Computation
- Auto-Tuning/Self-Adapting
- Fault Resilient Algorithms
- Reproducibility of Results
ppOpen-HPC (1/3)

- Open Source Infrastructure for development and execution of large-scale scientific applications on post-peta-scale supercomputers with automatic tuning (AT)
  - “pp” : post-peta-scale
- Five-year project (FY.2011-2015) (since April 2011)
  - P.I.: Kengo Nakajima (ITC, The University of Tokyo)
  - Part of “Development of System Software Technologies for Post-Peta Scale High Performance Computing” funded by JST/CREST (Japan Science and Technology Agency, Core Research for Evolutional Science and Technology)
    - Supervisor: Prof. Akinori Yonezawa (Co-Director, RIKEN AICS)
  - 4.5 M$ for 5 yr.
- Team with 7 institutes, >30 people (5 PDs) from various fields: Co-Design
  - U.Tokyo (4 divisions), Kyoto U., Hokkaido U., JAMSTEC
User’s Program

ppOpen-APPL
FEM FDM FVM BEM DEM

ppOpen-MATH
MG GRAPH VIS MP

ppOpen-AT
STATIC DYNAMIC

ppOpen-SYS
COMM FT

ppOpen-HPC

Optimized Application with
Optimized ppOpen-APPL, ppOpen-MATH
ppOpen-HPC (2/3)

- ppOpen-HPC consists of various types of optimized libraries, which covers various types of procedures for scientific computations.
  - ppOpen-APPL/FEM, FDM, FVM, BEM, DEM
- Source code developed on a PC with a single processor is linked with these libraries, and generated parallel code is optimized for post-peta scale system.
  - Users don’t have to worry about optimization tuning, parallelization etc.
    - Part of MPI, OpenMP
    - (OpenACC)
User’s Program

ppOpen-APPL
FEM
FDM
FVM
BEM
DEM

ppOpen-MATH
MG
GRAPH
VIS
MP

ppOpen-AT
STATIC
DYNAMIC

ppOpen-SYS
COMM
FT

ppOpen-HPC

Optimized Application with
Optimized ppOpen-APPL, ppOpen-MATH
ppOpen-HPC covers ...

- FEM
  Finite Element Method
- FDM
  Finite Difference Method
- FVM
  Finite Volume Method
- BEM
  Boundary Element Method
- DEM
  Discrete Element Method
ppOpen-APPL

- A set of libraries corresponding to each of the five methods noted above (FEM, FDM, FVM, BEM, DEM), providing:
  - I/O
    - netCDF-based Interface
  - Domain-to-Domain Communications
  - Optimized Linear Solvers (Preconditioned Iterative Solvers)
    - Optimized for each discretization method
  - H-Matrix Solvers in ppOpen-APPL/BEM
  - Matrix Assembling
  - AMR and Dynamic Load Balancing

- Most of components are extracted from existing codes developed by members
Program My_pFEM
use ppOpenFEM_util
use ppOpenFEM_solver

call ppOpenFEM_init
call ppOpenFEM_cntl
call ppOpenFEM_mesh
call ppOpenFEM_mat_init

do
   call Users_FEM_mat_ass
   call Users_FEM_mat_bc
call ppOpenFEM_solve
call ppOpenFEM_vis
   Time= Time + DT
endo

call ppOpenFEM_finalize
stop
end
ppOpen-HPC (2/3)

- ppOpen-HPC consists of various types of optimized libraries, which covers various types of procedures for scientific computations.
  - ppOpen-APPL/FEM, FDM, FVM, BEM, DEM
- Source code developed on a PC with a single processor is linked with these libraries, and generated parallel code is optimized for post-peta scale system.
- Users don’t have to worry about optimization tuning, parallelization etc.
  - Part of MPI, OpenMP
  - (OpenACC)
ppOpen-HPC (3/3)

- Capability of automatic tuning (AT) enables development of optimized codes and libraries on emerging architecture based on results by existing architectures and machine parameters.
  - Solvers & Libraries in ppOpen-HPC
  - OpenFOAM, PETSc etc.

- Target system is Post T2K system
  - 20-30 PFLOPS, FY.2015
  - Many-core based (e.g. Intel MIC/Xeon Phi)

- ppOpen-HPC helps smooth transition of users to new system
Schedule of Public Release
(with English Documents, MIT License)
We are now focusing on MIC/Xeon Phi

- **4Q 2012 (Ver.0.1.0)**
  - ppOpen-HPC for Multicore Cluster (Cray, K etc.)
  - Preliminary version of ppOpen-AT/STATIC
- **4Q 2013 (Ver.0.2.0)**
  - ppOpen-HPC for Multicore Cluster & Xeon Phi (& GPU)
  - available in SC’13
- **4Q 2014**
  - Prototype of ppOpen-HPC for Post-Peta Scale System
- **4Q 2015**
  - Final version of ppOpen-HPC for Post-Peta Scale System
  - Further optimization on the target system
ppOpen-HPC v.0.1.0
http://ppopenhpc.cc.u-tokyo.ac.jp/

- Released at SC12 (or can be downloaded)
- Multicore cluster version (Flat MPI, OpenMP/MPI Hybrid) with documents in English
- Collaborations with scientists

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<thead>
<tr>
<th>Component</th>
<th>Archive</th>
<th>Flat MPI</th>
<th>OpenMP/MPI</th>
<th>C</th>
<th>F</th>
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<td>ppOpen-AT/STATIC</td>
<td>ppohAT_0.1.0</td>
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What is new in Ver.0.2.0?

[http://ppopenhpc.cc.u-tokyo.ac.jp/](http://ppopenhpc.cc.u-tokyo.ac.jp/)

- Available in SC13 (or can be downloaded)

<table>
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<th>Component</th>
<th>New Development</th>
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<td>• OpenMP/MPI Hybrid Parallel Programming Model</td>
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<td>• Intel Xeon/Phi Version</td>
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<td>• Interface for ppOpen-MATH/VIS-FDM3D</td>
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<td>ppOpen-APPL/FVM</td>
<td>• Optimized Communication</td>
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<td>ppOpen-APPL/FEM</td>
<td>• Sample Implementations for Dynamic Solid Mechanics</td>
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<td>ppOpen-MATH/MP-PP</td>
<td>• Tool for Generation of Remapping Table in ppOpen-MATH/MP</td>
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<tr>
<td>ppOpen-MATH/VIS</td>
<td>• Optimized ppOpen-MATH/VIS-FDM3D</td>
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<tr>
<td>ppOpen-AT/STATIC</td>
<td>• Sequence of Statements, Loop Splitting (Optimized)</td>
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<td>• ppOpen-APPL/FVM</td>
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<td>• ppOpen-APPL/FDM • BEM</td>
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Collaborations, Outreaching

• Collaborations
  – International Collaborations
    • Lawrence Berkeley National Lab., National Taiwan University
  – We are happy to do any types of research collaborations

• Outreaching, Applications
  – Large-Scale Simulations: Most Important for Demonstrations of the Potential of ppOpen-HPC
    • JHPCN (Joint Usage/Research Ctr. for Interdisciplinary Large-scale Information Infrastructures )
    • ppOpen-AT, ppOpen-MATH/VIS, ppOpen-MATH/MP, Linear Solvers
  – SPNS Workshop (2012, 2013)
  – Tutorials, Classes
図1 NICAMとIOモジュールの海面気圧
Challenge (FY2013): A test of a coupling simulation of FDM (regular grid) and FEM (unconstructed grid) using newly developed ppOpen-MATH/MP Coupler

c/o T. Furumura

**FDM: Seismic Wave Propagation**
- Model size: 80x80x400 km
- Time: 240 s
- Resolution (space): 0.1 km (regular)
- Resolution (time): 5 ms (effective freq. < 1 Hz)

**FEM: Building Response**
- Model size: 400x400x200 m
- Time: 60 s
- Resolution (space): 1 m
- Resolution (time): 1 ms

**ppOpen-MATH/MP:** Space-temporal interpolation, Mapping between FDM and FEM mesh, etc.
from Post-Peta to Exascale

• Currently, we are focusing on Post-T2K system by manycore architectures (Intel Xeon/Phi)

• Outline of the Exascale Systems is much clearer than which was in 2011 (when we started this project).
  – Feasibility Study in Japan towards Exascale System
    • More complex, and huge system
    • More difficult to extract performance of applications
  – Frameworks like ppOpen-HPC are really needed
  – Smooth transition from post-peta to exa will be possible through continuous development and improvement of ppOpen-HPC (We need funding for that !)

• Research Topics in Exascale Era
  – Power-Aware Algorithms/AT
  – Communication/Synchronization Reducing Algorithms