Joint Usage / Research Center for Interdisciplinary Large-scale Information Infrastructures

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Innovative Multigrid Methods II

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Background

- Multigrid (MG) for linear equations
  - ✓ Scalable multilevel method for solving linear equations
  - ✓ GMG (Geometrical Multigrid) and AMG (Algebraic)
  - ✓ Generally, number of iterations until convergence for multigrid method is kept constant as the problem size changes.
  - ✓ The parallel multigrid method is expected to be one of the most powerful tools on exa-scale systems.
  - ✓ Many sophisticated methods for efficiency of MG have been developed for ill-conditioned problems derived from real-world scientific and engineering applications.
- MG for parallel in Space and Time
  - ✓ Parallel computation in time direction of simulation
  - ✓ It adds new dimension to ordinary parallelization of scientific simulation calculation
- Robust and efficient algorithms for GMG and AMG methods, and PinST towards the Exascale/Post-Moore Era.

Development: 3-Year Project (FY.2020 to 2022)

- GMG and AMG:

✓ Research on smoothers

Kawai, Ida, Nakajima, Bolten, Wellein, Alappat, Schreiber

- ➢ Multicolor-block GS smoother for AMG is the original smoother developed by Our project members.
- ➢ SpMV based smoothers such as Chebyshev smoother are known. We will also consider to accelerate these simple smoothers by fast sparse matrix data structures

✓ Lower precision utilization for performance

Nakajima, Hoshino, Wellein, Alappat, Schreiber, Ohshima

- ➢ We will study on how to use the lower precision calculations for efficient multigrid solvers.
- ➢ First, we will investigate various lower precision usage for solvers such as only coarse level calculation or lower precision Krylov preconditioning.
- ➢ After we checked effective lower precision usage patterns, then we will study selection methods according to the problem matrix.

✓ Acceleration technique with file IO optimization and communication

Hanawa, Ohshima, Fujii, Nakajima, Yoda

- ➢ Parallel linear solvers and mesh generation routines often need to read and write distributed matrix files. We will investigate efficient usage of the burst buffer functionality of supercomputers for mesh generation or sparse linear solvers.
- ➢ As for halo communication, we will study fast Halo communication with user-level direct RDMA on Tofu, that will be available in Fugaku, post-Kei computer.

✓ Evaluation with weak scaling and large sized problems

Nakajima, Fujii, Marques, Ida

- ➢ Our project already has spent several years to implement multigrid solvers such as GMG and AMG. We will analyze the performance of the solvers, and check the space for improvement.

- New approaches for PinST

Ono, Iizuka, Fujii, Bolten, Iwashita, Takahashi, Speck, Schreiber, Yoda, Chen

- ✓ Coarse level solver in Parareal method Iizuka and Ono studied the convergence of the Parareal method for hyperbolic PDEs focusing on coarse solver.
- ✓ Convergence analysis on MGRIT preconditioning for linear problems
- ✓ Time Segmented Correction (TSC) method and its enhancement, which is a new parallel time integration method for non-linear problems.

Plan for FY.2020

This project is a succession of previous JHPCN project “Innovative Multigrid methods”. The current state of the research will be presented as the research results of the previous project. Here, we list up our plans on FY.2020. As a first year, we will do fundamental researches including the following items.

- GMG
  - ✓ Researches on sparse matrix data structure like SELL-C- σ
  - ✓ Specific application optimization including pGW3D-FVM
  - ✓ Communication optimization with Pipelined CG solver
  - ✓ File IO optimization in Mesh Generation by IME
  - ✓ Scalability Evaluation by Adaptive Multilevel hCGA (AM-hCGA)
- AMG
  - ✓ Researches on sparse matrix data structure like SELL-C- σ
  - ✓ Researches on smoothers like preconditioned Chebyshev smoothers and MS-BMC-GS.
  - ✓ Communication optimization with Pipelined CG solver
  - ✓ Communication optimization on halo communication using user-level RDMA
  - ✓ Further Improvement of the Convergence by Parallel Reordering/Aggregation
- PinST
  - ✓ MGRIT Preconditioning convergence analysis
  - ✓ Research on Parareal method for hyperbolic PDEs
  - ✓ TSC method application to pHEAT-3D
  - ✓ Research on PinST method to Navier-Stokes applications
  - ✓ Research on TSC method for simulation codes based on explicit method.