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Innovative Multigrid Methods II

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Purpose and Background

Robust and efficient algorithms for Multigrid(MG) methods towards the Exascale Era.

- Multigrid (MG) for linear equations
  - ✓ Scalable multilevel method for solving linear equations
  - ✓ GMG (Geometrical Multigrid) and AMG (Algebraic)
  - ✓ 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

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

- GMG and AMG:
  - ✓ Research on smoothers

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

- ➢ Multicolor-block GS smoother for AMG is the original smoother developed by Our project members.
- ➢ We will also consider to accelerate the smoothers by SIMD oriented sparse matrix data structures such as SELL-C-σ

✓ 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

- ➢ 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 RDMA interface on Tofu, that will be available in Fugaku.

✓ Evaluation with weak scaling and large sized problems

Nakajima, Fujii, Marques, Ida, Tanaka

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

- New approaches for PinST

Ono, Fujii, Bolten, Iwashita, Takahashi, Speck, Schreiber, Yoda, Chen, Caklovic, Miyagi

- ✓ MGRIT preconditioning for linear problems
- ✓ New approach based on the parareal method for explicit time marching applications
- ✓ Time Segmented Correction (TSC) method and its enhancement, which is a new parallel time integration method for non-linear problems.

Plan for FY.2022

This project is the final year of the 3-year project. The current state of the research will be presented as the research results of the last year. Here, we list up our plans on FY.2022.

- GMG
  - ✓ Researches on sparse matrix data structure like SELL-C- σ
  - ✓ Lower precision GMG solver
  - ✓ Scalability Evaluation by Adaptive Multilevel hCGA (AM-hCGA)
- AMG
  - ✓ Researches on AM-hCGA algorithm without ParMETIS
  - ✓ Communication optimization on halo communication using user-level RDMA on Supercomputer FX1000.
- PinST
  - ✓ scaling enhancement of MGRIT solver such as MGRIT preconditioning and parallelism assignment at the coarse levels.
  - ✓ Application of TSC method for coase-grained molecular dynamics problem
  - ✓ PinST method of explicit method for fluid problems