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FRANCE 2030
PROGRAMME DE RECHERCHE
NUMÉRIQUE POUR L'EXASCALE

ExaMA Work Package 3

Solvers

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ExaMA – Exa-scale Methodologies and Algorithms

Overview

WP3 Objectives

Objective 1 Design novel or improved numerical kernels, reduce the computational complexity, memory footprint and data movement, mixed arithmetic and data compression

Objective 2 Design coupled physic solvers that rely on state-of-the-art optimized mono-physics solvers

WP3 Tasks

- T3.1 Domain decomposition methods with subspace-correction
- T3.2 Exploiting data-sparsity, multiple precision and data compression
- T3.3 Adaptive solution strategies for high performance multiphysical and multiscale models

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Progress

Key Achievements (2024-2025) and milestone status

Achievement 1 *The majority of positions filled*

Achievement 2 *Results regarding mixed-precision solvers and extended domain decomposition techniques*

Milestones

- *Work in progress*
- *Towards a first set of methods to be deployed and tested (WP7 support)*
- *Continuous interaction with other WPs to gather needs and track answers*
- *Mini/proto apps on the way*

Deliverable Status

Deliverable	Due Date	Status
D3.1	Annual report 2025	Submitted
D3.2	12/2025	release Composyx v1.4.0
		release HPDDM (see below)
		release PROMISE (see below)
D3.3	Benchmarking analysis report 2025	Ongoing

Deliverable Status

Added features to HPDDM

- Better off-loading to NVIDIA GPUs (by Raphaël Zanella and Erik Fabrizzi)
- Support for applying the transpose of a preconditioner to a single vector or a block of vectors (by Raphaël Zanella)
- Support for analysis by block of MUMPS for the coarse operator (by Pierre Jolivet)

Added features to Promise

- Automatic precision adjustment with arbitrary-sized formats

Added features to Composyx

- Attend presentation tomorrow

In collaboration with PC2 ExaSoft.

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Technical Highlights

Technical Highlight 1.a

Contribution: Domain decomposition - GenEO Method

Domain decomposition splits a large problem into smaller parts that can be solved separately. **GenEO based preconditioning** – Lukas Spies, Erik Fabrizzi & Tom Caruso

- Applying GenEO preconditioner to coupled domain saddle point problem using domain decomposition;
- Improving GPU performance of GenEO in HPDDM/PETSc to better address complexity of saddle point problems;
- Mixed precision to reduce the memory footprint and computation time of GenEO in HPDDM on GPU to prepare the method for exascale systems.

Technical Highlight 1.b

Contribution: Domain decomposition for indefinite linear systems

Extended GenEO Domain Decomposition – E. Parolin & F. Nataf

- Coarse space for RAS with approximate/exact local solves and non-symmetric problems with provable efficiency
- Implemented in ffddm (parallel DD library of FreeFEM developed by P.H. Tournier)

Technical Highlight 2

Contribution: Mixed Precision Krylov Methods

Leveraging multiple numerical precisions to reduce memory footprint and accelerate Krylov-based solvers.

Mixed precision GMRES – Erik Fabrizzi & Alexandre Tabouret

- Integration of augmentation techniques within a mixed-precision GMRES framework;
- Dynamic adaptation of the precision used in matrix–vector products during execution;
- Effectively reducing runtime and memory complexity, as well as improving convergence rates.

Technical Highlight 3.a

Autotuning Frameworks for Precision and Parameter Optimization for HPC applications

Precision Autotuning for Numerical Algorithms

Objective:

- Design a novel autotuning algorithm that will automatically provide arbitrary precision codes, from a required accuracy on the computed results.

Highlights of work:

- Enabled support for user-defined precision formats in PROMISE with high-fidelity precision emulation on mathematical functions
- Developed a PROMISE-based mixed-precision benchmarking framework, supporting one-click precision autotuning executed in parallel across multiple benchmarks
- Added containerized support (docker) for PROMISE to enable fast and reproducible deployment
- Developed a containerized, task-parallel benchmarking framework that integrates PROMISE with GNU Parallel to concurrently evaluate multiple numerical algorithms, significantly reducing wall-clock time while ensuring consistent and reproducible HPC performance measurements.

Technical Highlight 3.b

Autotuning Frameworks for Precision and Parameter Optimization for HPC applications

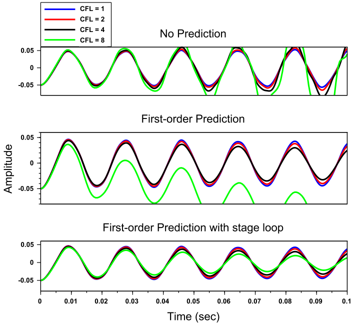
Parameter Autotunning for Ultra-high Performance Computing for Partitioned Coupling

Objective:

- Identification of numerical parameters in coupling algorithms and development of autotuning strategies.

Highlights of work:

- Survey of various time integration schemes.
- Developed a model app (FSI coupling) for testing purpose.
- Analysis of basic coupling strategies & parameter identification.
- Software frameworks: ICoCo, MEDCoupling, PETSc.



Collaboration

Inter-WP Collaboration

With WP1 *Technical meeting and exchanges on numerical methods for coupled problems*

With WP2 *Neural Network to learn a preconditionner used with FGMRES in mixed arithmetic*

With WP4 *Technical meeting to integrate linear solvers in inverse problem solvers (Hawen)*

With WP7 *Regular meetings with package developers*

External Collaboration

- Collaboration with other PCs:
  - *With PC2 on mixed arithmetic and composability*
  - *Indirectly with PC5 through WP7 for software releases and mini/proto-app*
- International collaborations: *Nothing significant so far, but perspectives over the years*

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Next Steps

Plans for 2026

Plan 1 *Reinforce collaborations with WP7 to benchmark our packages*

Plan 2 *Minimize 64-bit computation*

Plan 3 *Implementation and generalization of the automation of arithmetic selection*

Plan 4 *Academic progress and synergies of early stage researchers funded by ExaMA and beyond*

Challenges and Risks

- Challenge 1 *One PhD recruitment to be completed*
- Challenge 2 *Sustainable interactions with WP7 to transfer research outcomes to applications*
- Challenge 3 *Affordable metrics for automation of arithmetic and algorithmic optimization*
- Challenge 4 *Assessing energy performance of algorithms*

Conclusion

Summary

- WP3 is *on track.*
- Key achievements:
  - *The majority of positions filled*
  - *Results regarding mixed-precision solvers and extended domain decomposition techniques*
- Next priorities: *preserve synergy between various teams*

Questions ?