1st OpenFOAM HPC Challenge (OHC-1): Software Track Summary

JULY 1, 2025, VIENNA

Mini-symposium to be held in the auspices of the
2025 OpenFOAM Workshop

Organized by the OpenFOAM HPC Technical Committee (TC)

Presented by:
Sergey Lesnik, Gregor Olenik, Mark Wasserman

Rules (Software/Open Track)

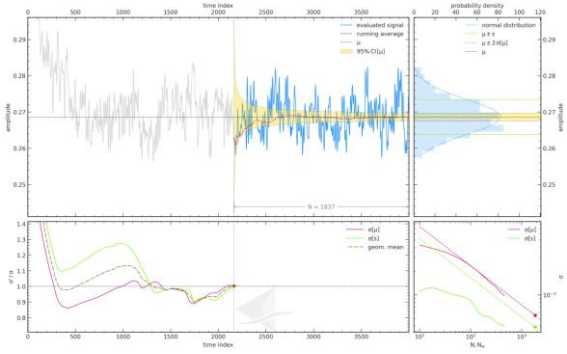
- **Objective: Showcase code optimizations that improve performance (time, energy), whilst retaining the basic level of accuracy as demonstrated with standard OpenFOAM**
- **Hardware: unconstrained**
- **Software: unconstrained, OpenFOAM-based code**
- **Case setup: occDrivAerStaticMesh, with fixed mesh and physical modelling (temporal and spatial discretization, turbulence model)**
  - Steady-state, incompressible flow
  - RANS with kw-SST turbulence model
  - Pre-defined fvSchemes (changes allowed but have to be reported)
- **Proposed topics for investigation: accelerators, pre-/post-processing (I/O), mixed-precision, linear solvers, renumbering/decomposition**

Validation via Force Coefficients

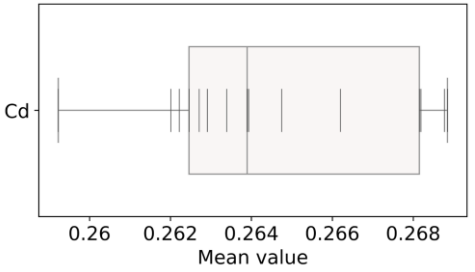
OF Reference Values (fine)

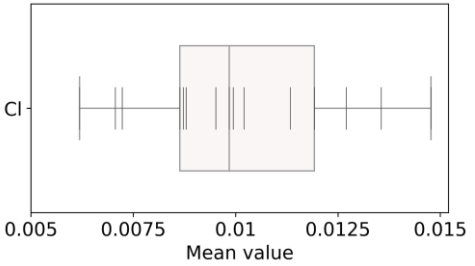
Cd | 2.62E-01
Cl | 7.87E-02
Cs | 1.16E-02

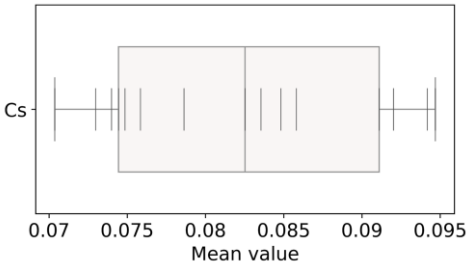
- Extracted profiles at run time
- Participants of the software track were required to extract force convergence and analyze using meanCalc
- Results were reported via submission sheet and time series
- Data analysis team double checked and cross compared values
- Reported data with requirements
- Check validity of 2*sigma(mu) < 0.0015



Total timesteps [nread]	4000	4000	4000
Averaging start timestep [nskip]	1723	1723	1723
Averaging samples [nused]	2277	2277	2277
Mean value μ	0.2627	0.0740	0.0149
Error Mean Value $\sigma(\mu)$	0.00065	0.00165	0.00166
95% conf. int. on mean $2*\sigma(\mu)$	0.0013	0.0033	0.0033
Standard deviation s	0.0052	0.0180	0.0088
Error Standard Deviation $\sigma(s)$	0.0005	0.0012	0.0012







Contributors

- **60+ data points contributed by 5 contributors:**
  - Engys
  - CINECA
  - Huawei
  - Wikki GmbH
  - KIT/TUM

Thank you!

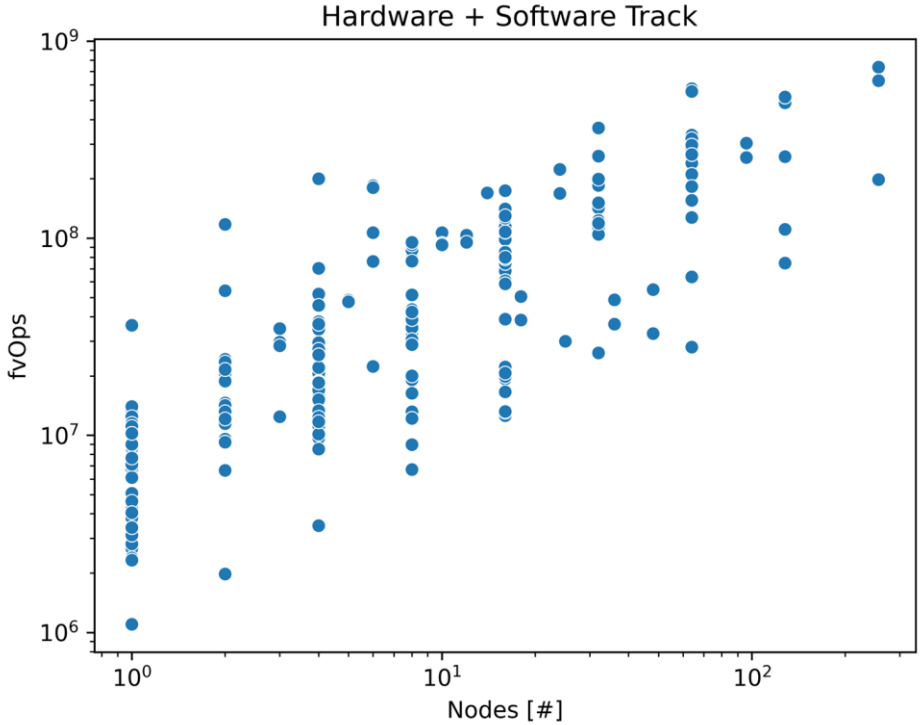
Software Track in Numbers

	Software Track	Hardware Track	
Submitted Results	62	175	26%
Min. energy per Iteration [Ws]	1867	2613	-28%
Max. performance [MfvOps]	737	629	+17%
Min. time step [s]	0.11	0.37	-70%

Metrics

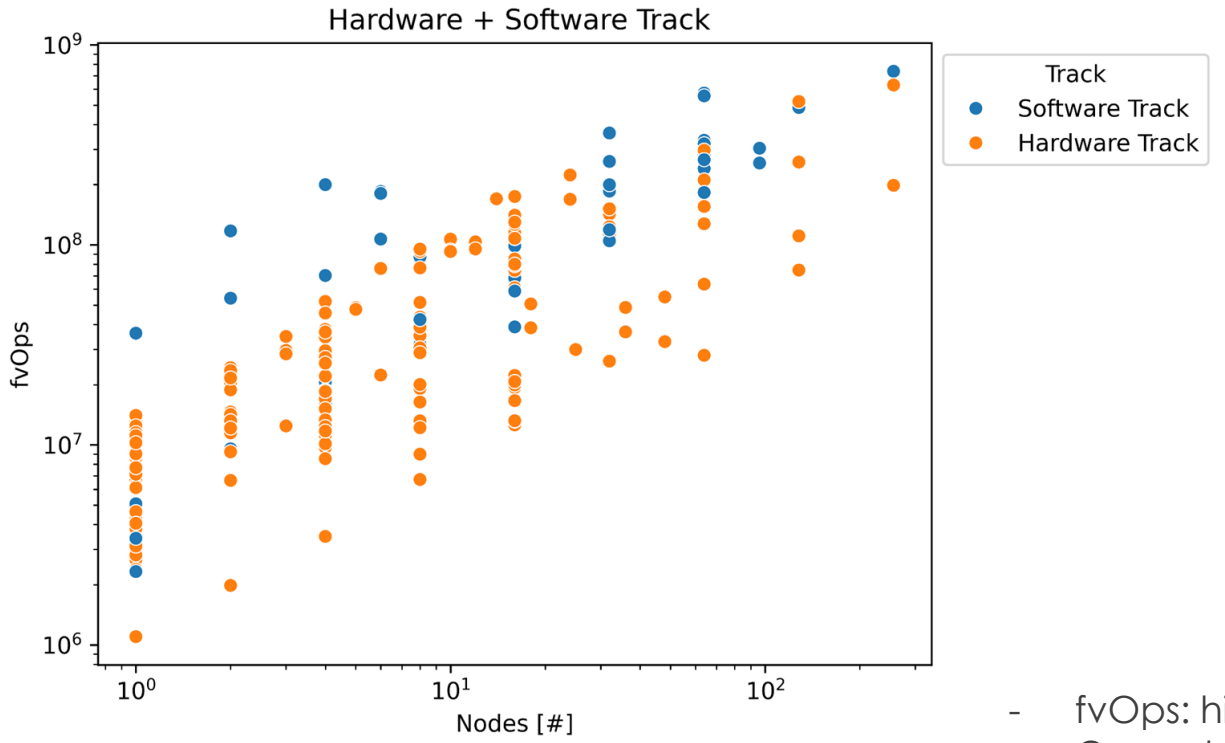
- **Software Track**
  - Single- and Multi-node Scalability
  - Time-to-solution, excl. Pre-processing (decomposition, renumbering) and initialization (potentialFoam)
  - Energy-to-solution (energy-per-iteration)
  - FVOPS (Finite-volume operations per second)
  - Accuracy w.r.t reference solution obtained with standard OpenFOAM (hardware track)
    - Mean and variance of aerodynamic coefficients

Breakdown of Contributions (Statistics)



- fvOps: higher is better
- On node basis

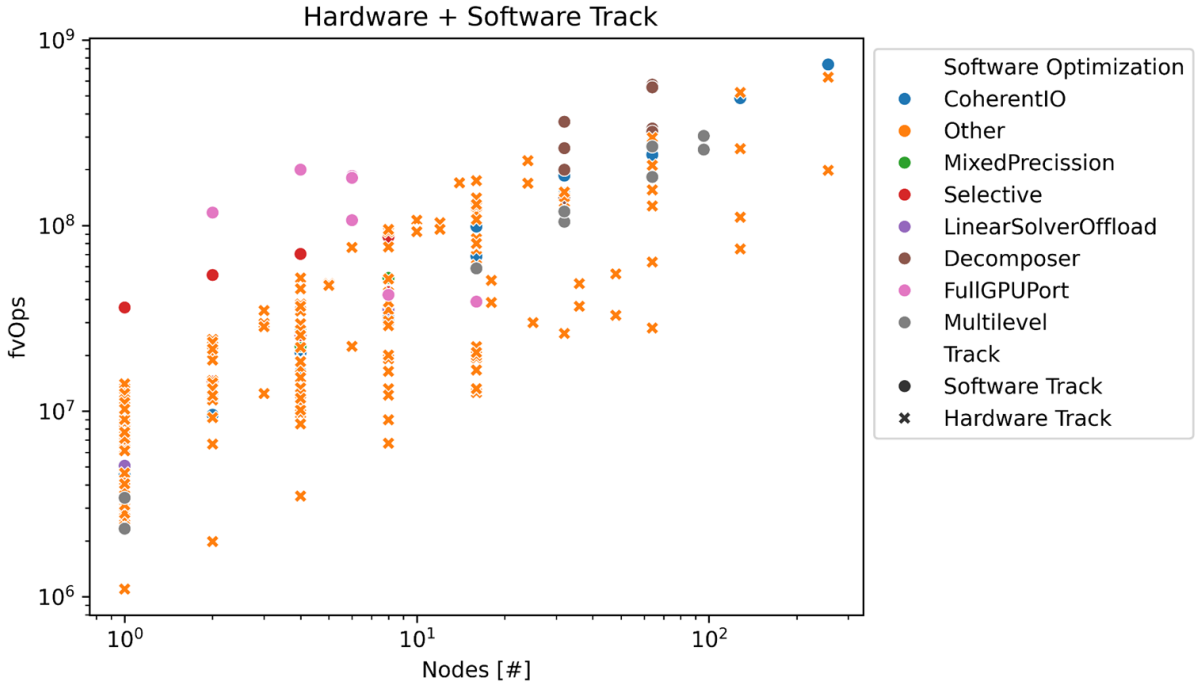
Breakdown of Contributions (Statistics)



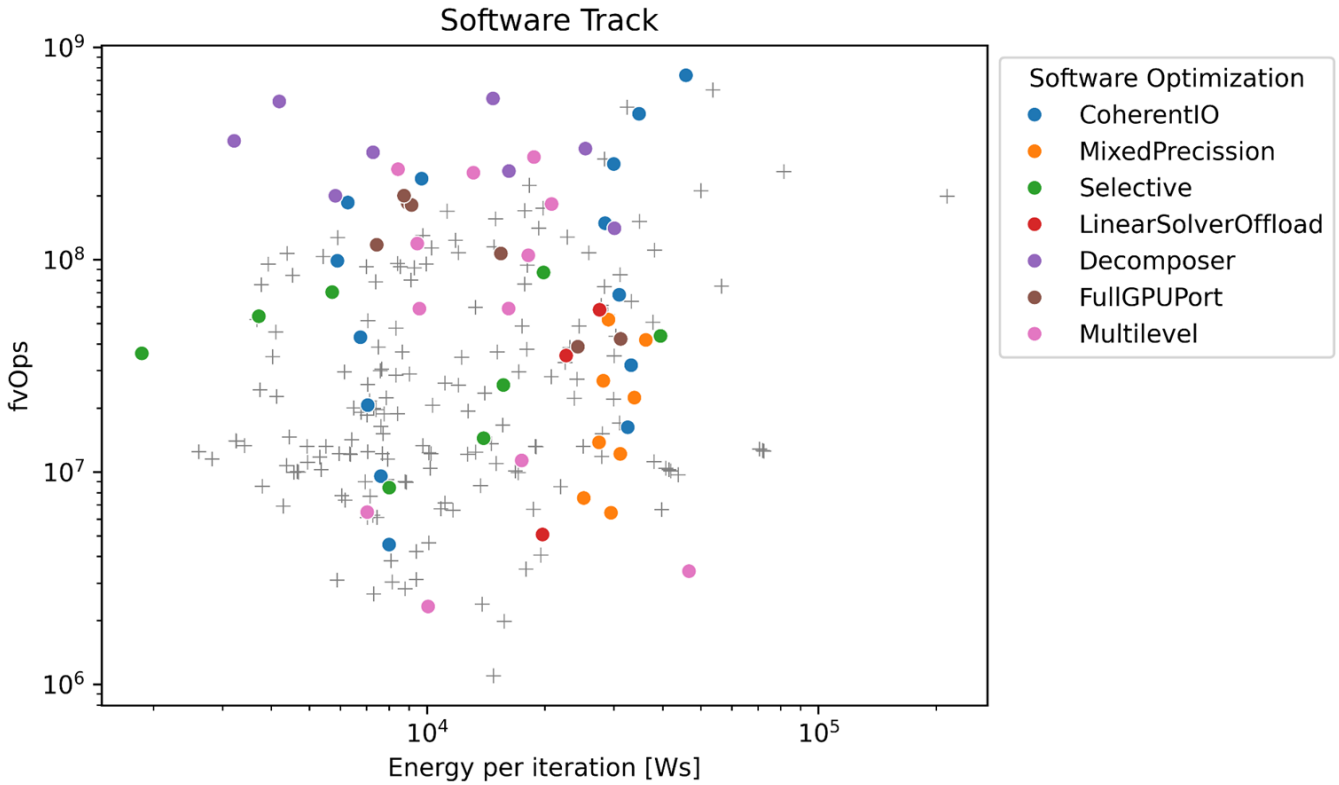
- fvOps: higher is better
- On node basis

Breakdown of Contributions by Category

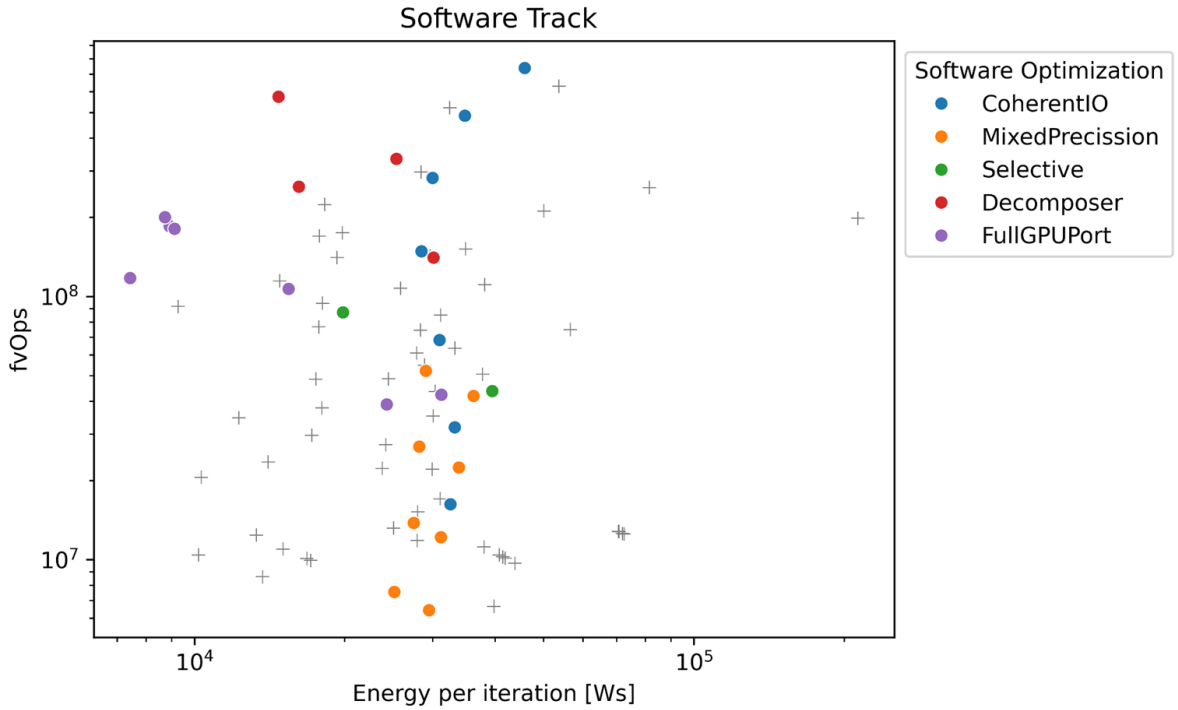
- Full GPU ports
- Linear Solvers on GPUs
- Decomposition Optimisations
- Mixed precision,
- Selective Memory Allocation
- Coherent I/O



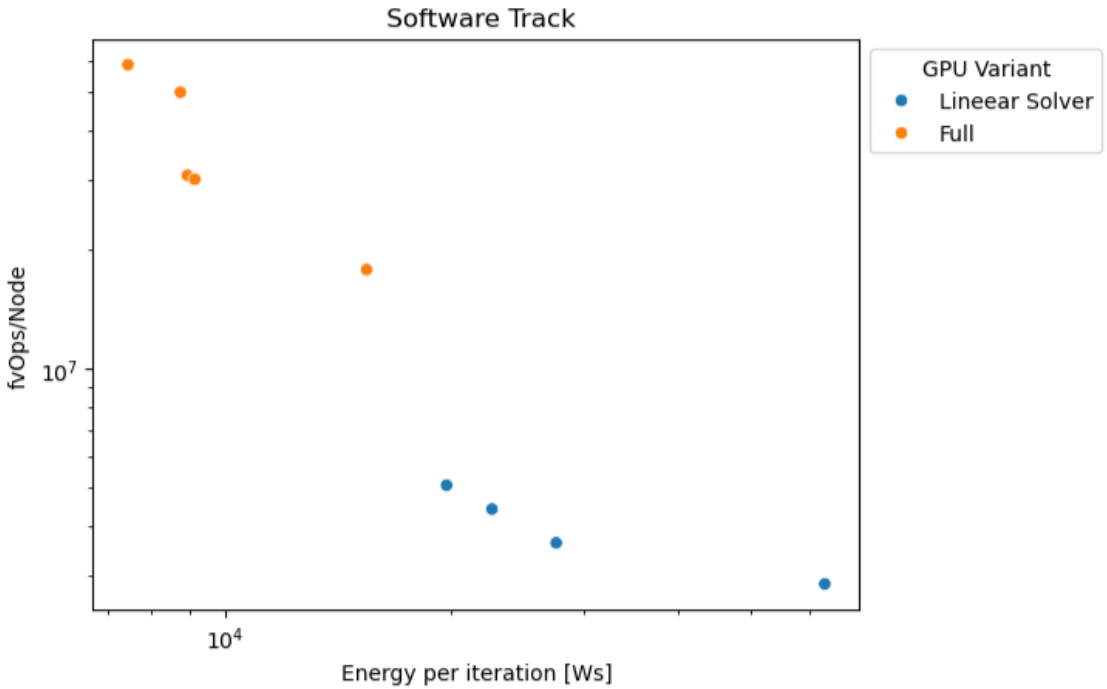
Breakdown of Contributions by Category



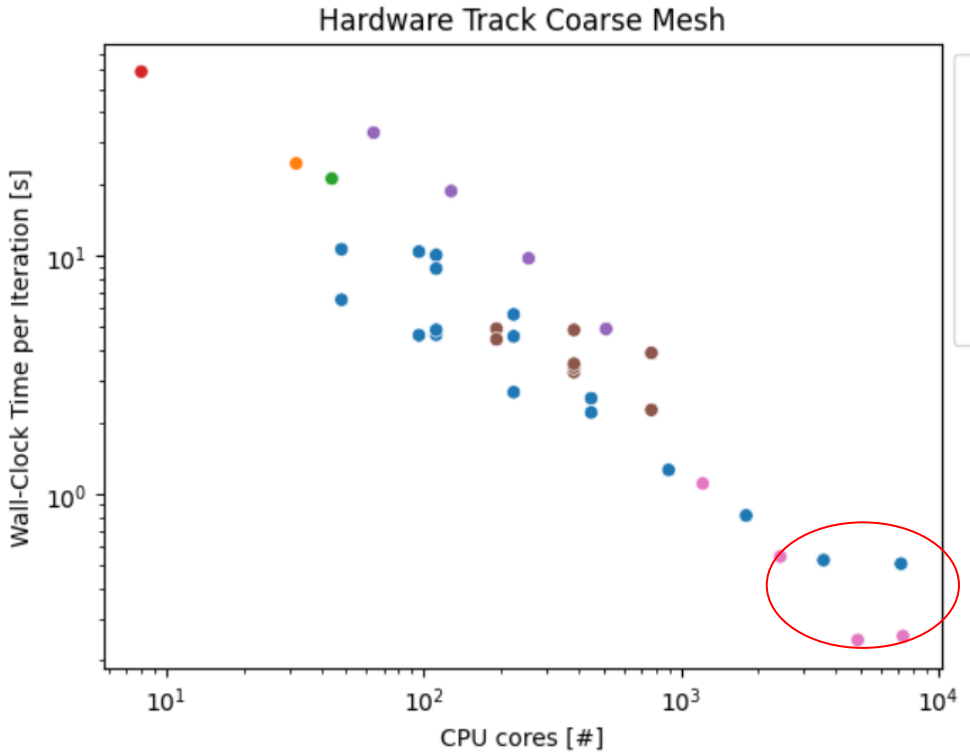
Breakdown of Contributions by Category



Full GPU Port vs GPU Linear Solver Potential



Software Optimizations Potential



Better Performance on older gen CPU thanks multi level decomposition

Conclusions and Future Work

- **Submission addressed various areas of optimization**
- **Full GPU ports show promising results**
- **Software optimizations can outperform several generation-jumps in hardware**
- **Currently we had only approximately 20% of total submissions in the software track**
- **Promote a more relevant benchmark case than LidDrivenCavity3D**
- **Derive best practice based on submissions**
- **Publication of results**