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# Massively Parallel & Lower Precision Accelerator Hardware as Trends in HPC and its Application to CFD

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**Key Words:** *Time-simultaneous Newton-Krylov-Multigrid, prehandling, lower precision, accelerator hardware, HPC, CFD.*

The aim of this talk is to present and to discuss how modern, resp., future High Performance Computing (HPC) facilities regarding massively parallel hardware with millions of cores together with very fast, but lower precision accelerator hardware can be exploited in numerical simulations of PDEs so that a very high computational, numerical and hence energy efficiency can be obtained. Here, as prototypical extreme-scale PDE-based applications, we concentrate on nonstationary flow simulations with hundreds of millions or even billions of spatial unknowns in long-time computations with many thousands up to millions of time steps. For the expected huge computational resources in the coming exascale era, such type of spatially discretized problems which typically are treated sequentially, that means one time after the other, are still too small to exploit adequately the huge number of compute nodes, resp., cores so that further parallelism, for instance due to the time, might get necessary.

In this context, we discuss how "simultaneous-in-time" Newton-Krylov-Multigrid approaches can be designed which allow a much higher degree of parallelism (in space). Moreover, to exploit current accelerator hardware in lower precision (for instance, GPUs or ARM), that means mainly working in single or even half precision, we discuss the concept of "prehandling" (in contrast to "preconditioning") of the corresponding ill-conditioned systems of equations, for instance arising from Poisson-like problems. Here, we assume a transformation into an equivalent linear system with similar sparsity but with much lower condition numbers so that the use of lower precision hardware (particularly for NVIDIA V100 / A100) might get feasible. In our talk, we provide numerical results as "proof-of-concept" and discuss the open problems, but also the challenges, particularly for exploiting accelerator hardware for PDEs.

## REFERENCES

[1] Ruda, D.; Turek, S.; Zajac, P.; Ribbrock, D.: *Very Fast Finite Element Poisson Solvers on Lower Precision Accelerator Hardware - A Proof-of-Concept Study for NVIDIA Tesla V100*, Ergebnisberichte des Instituts für Angewandte Mathematik Nummer 647, Fakultät für Mathematik, TU Dortmund, 647, 2021.

[2] Dünnebacke, J.; Turek, S.; Zajac, P.; Sokolov, A.: *Increased space-parallelism via time-simultaneous Newton-multigrid methods for nonstationary nonlinear PDE problems*, International Journal of High Performance Computing Applications, online, https://doi.org/10.1177/10943420211001940, 2021.

[3] Turek, S.; Ruda, D.; Ribbrock, D.; Zajac, P.: *Eine Machbarkeitsstudie zu schnellen FEM-Poisson-Lösern auf Beschleunigerhardware als Beispiel für Hardware-orientierte Numerik*, Rundbrief GAMM, 4-12, Rundbrief 1/2021, 2021.