Massively parallel & low precision accelerator hardware as trends in HPC - How to use it for large scale simulations allowing high computational, numerical and energy efficiency with application to CFD

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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 low precision accelerator hardware can be exploited in numerical simulations 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 w.r.t. time, might get necessary.

In this context, we discuss how ”parallel-in-space simultaneous-in-time” Newton-Multigrid approaches can be designed which allow a much higher degree of parallelism. Moreover, to exploit current accelerator hardware in low precision (for instance, GPUs or TPUs), that means mainly working in single precision 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 low-precision hardware might get feasible. In our talk, we provide for both aspects preliminary numerical results as ”proof-of-concept” and discuss the open problems, but also the challenges, particularly for incompressible flow problems.

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