A massively scalable distributed multigrid framework for nonlinear marine hydrodynamics -
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The focus of this article is on the parallel scalability of a distributed multigrid framework, known as the DTU Compute
GPUlab Library, for execution on graphics processing unit (GPU)-accelerated supercomputers. We demonstrate near-
ideal weak scalability for a high-order fully nonlinear potential flow (FNPF) time domain model on the Oak Ridge Titan
supercomputer, which is equipped with a large number of many-core CPU-GPU nodes. The high-order finite difference
scheme for the solver is implemented to expose data locality and scalability, and the linear Laplace solver is based on an
iterative multilevel preconditioned defect correction method designed for high-throughput processing and massive
parallelism. In this work, the FNPF discretization is based on a multi-block discretization that allows for large-scale
simulations. In this setup, each grid block is based on a logically structured mesh with support for curvilinear
representation of horizontal block boundaries to allow for an accurate representation of geometric features such as
surface-piercing bottom-mounted structures—for example, mono-pile foundations as demonstrated. Unprecedented
performance and scalability results are presented for a system of equations that is historically known as being too
expensive to solve in practical applications. A novel feature of the potential flow model is demonstrated, being that a
modest number of multigrid restrictions is sufficient for fast convergence, improving overall parallel scalability as the
coarse grid problem diminishes. In the numerical benchmarks presented, we demonstrate using 8192 modern Nvidia
GPUs enabling large-scale and high-resolution nonlinear marine hydrodynamics applications.

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