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FEMPAR: A DOMAIN-DECOMPOSITION-BASED CODE FOR PARALLEL FINITE ELEMENT MULTIPHYSICS SIMULATIONS

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In this talk we describe the ideas and algorithms we developed and implemented in FEMPAR, a massively parallel finite element multiphyiscs code. It is based from inception on domain decomposition and an abstract and powerful implementation of physics-based preconditioners. An element-based partition of the domain and ghost element information that permits, in a multiphysics context, to locally define the degrees of freedom and the unknowns that must be communicated among processors.

The solution of positive definite linear systems is performed using a multilevel domain decomposition methods. In particular, we present a fully-distributed, communicator-aware, recursive, and interlevel-overlapped message-passing implementation of the multilevel balancing domain decomposition by constraints (MLBDDC) preconditioner. We have carried out a comprehensive weak scalability analysis of the proposed implementation for the Laplacian and linear elasticity problems. Excellent weak scalability results have been obtained up to 458,752 processors and 1.8 million MPI tasks for the Poisson and elasticity problems, making FEMPAR part of the HighQ club of the highest scaling codes on JUQUEEN.

However, in order to have an impact in science and industry, we must extend scalability to the most challenging applications, since these are the ones that really require extreme scale simulation tools, e.g., multiscale, multiphysics, nonlinear, and transient problems. To do that we employ block preconditioning techniques that allow us to decouple complex multiphysics problems into simpler (probably) one physics simulations. We will show how we have implemented complex (recursive) block preconditioning strategies in FEMPAR using abstract definitions of operators, and how this framework can be applied to different multiphysics solvers.