

Hybrid-parallel Methods for Large-scale Gradient-based Structural Design Optimization

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In this paper, we describe and evaluate the parallel implementation and performance of a hybrid parallel finite-element code for large-scale gradient-based optimization. Realistic high-fidelity structural design optimization problems for modern composite aircraft involve hundreds to thousands of load cases, tens of thousands of design variables and up to hundreds of thousands of constraints. For these optimization problems, the single most expensive computational operation is the evaluation of the derivatives constraints. This can be a significant bottleneck during the optimization, even when efficient gradient evaluation methods, such as the adjoint method, are employed. In this paper, we describe methods for analysis and gradient-evaluation that exploit the structure of these large-scale optimization problems to achieve optimal computational performance on machines built using clusters of multi-core CPUs. In this research we have extended the capabilities of our in-house parallel finite-element code called the Toolkit for the Analysis of Composite Structures (TACS) to use a hybrid parallel architecture that combines the Message Passing Interface (MPI) and POSIX threads (pthreads). This two-level hybrid scheme enables us to achieve finer-grain parallelism on performance-critical tasks required for gradient evaluation. In particular, we use this hybrid-scheme to achieve better scalability when evaluating the partial derivatives required for the adjoint and when solving multiple adjoints simultaneously. We demonstrate the efficiency of the implementation of the new algorithms on a large-scale optimization problem with hundreds of load cases, thousands of design variables and thousands of constraints.