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ON THE NUMBER OF SUBPROBLEM ITERATIONS PER COUPLING STEP AND MONITORING CONVERGENCE IN PARTITIONED FLUID-STRUCTURE INTERACTION SIMULATIONS

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ABSTRACT

In literature, the costs of strong (implicit) coupling schemes for fluid-structure interaction are typically assessed by the number of coupling iterations required per time step, while ignoring the internal iterations within the nonlinear subproblems. We demonstrate that the internal iterations have a significant influence on the computational cost of the coupled simulation. Particular attention is paid to how limiting the number of iterations within each solver call can shorten the overall run time, as it avoids polishing the subproblem solution using unconverged coupling data. Specifically, it is demonstrated that performing subproblem iterations until the solver is fully converged in each call does minimize the number of coupling iterations but does not lead to minimal computational time. Instead, under the assumption of constant subproblem iteration cost, the optimum is found by minimizing a weighted sum of both coupling and subproblem iterations.

When analysing the optimal choice of the coupling steps and the internal iterations of the non-linear solvers, the question automatically arises as to when a time step can be considered converged. A variety of convergence criteria exists, but they all compare a quantity representative of the change in interface data between successive coupling iterations, e.g., the interface residual, to a prescribed tolerance. The choice of this tolerance value is often ad hoc and based on experience. Moreover, its relationship to the tolerances of the subproblems is unclear and often not considered, even though the accuracy of the coupled simulation is inherently linked to that of the solutions of the subproblems. We address this shortcoming by discussing a newly introduced criterion that does not require the choice of a coupling tolerance but bases the convergence of the time step on the number of subproblem iterations to reach convergence. This not only eliminates the inconvenient choice of a coupling tolerance but also allows one to better judge the accuracy with which the subproblems should be solved. The new criterion can be applied to black-box solvers under the condition that they provide information on whether they have converged and on how many subproblem iterations have been run. Although the focus of this work is on fluid-structure interaction simulations, the criterion applies to any type of coupling of black-box solvers under the given minor condition.

[1] T. Spenke, N. Delaisse, J. Degroote and N. Hosters. On the number of subproblem iterations per coupling step in partitioned fluid-structure interaction simulations. IJNME, 2023.