A computationally efficient algorithm for strongly coupled multi-physics problems using a partitioned two-scale approach

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ABSTRACT

In many time-dependent coupled problems, the admissible numerical time stepping size is typically limited by constraints such as time-scale issues or stiffness in a subsystem. Therefore, by using a naïve approach, the constraints impose restrictions on the entire system integration in time, and leading to unreasonably high computational costs, depending on the problem type. In this work, we present a two-scale prediction-correction based solution strategy for partitioning techniques as an algorithm, aiming to reduce the total computational costs for coupled systems, in the sense that the remaining subsystems without time step size constraints are attempted to be solved less frequently within the time integration. Although the computational cost is our primary concern, other important aspects of a general partitioning strategy, such as solution accuracy and time lagging issue in the coupling has been targeted to be satisfyingly achieved. As a case study, the algorithm has been applied to a time-dependent modeling of the Earth's mantle convection [1, 2], using a locally conserved mass finite element method [3]. A rigorous analysis of the test case clearly demonstrated the capability of the algorithm by means of a substantial performance gain. Ultimately, the optimal tuning of the algorithm using a run-time error estimation has been investigated by utilizing the intrinsic flexibility of the algorithm which gives a full control on the cost and accuracy.

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