Prospective Applications Of Asynchronous Time-Integration For Multiphysics Simulations

S. Karimi

FullRank Software, LLC., Houston, TX, USA

Abstract

Multi-physics problems have become an extremely important part of modern engineering and science practice. Due to the variety in the involved processes, disparate temporal and spatial scales are a characteristic of these problems. Development and study of multi-scale numerical algorithms to resolve spatial and temporal disparity has become one of the most vibrant research topics among computational scientists. These types of algorithms provide the means to bridge the gap across different mathematical scales. Asynchronous coupling methods allow flexible choice of integration methods (either temporal or spatial) in different regions of the spatial domain.

One of the promising approaches to multi-scale modeling is the domain decomposition technique. In this approach, the computational domain is split into a number of subdomains. The numerical solution in each subdomain is computed using a method that can be different from the one used in other subdomains. A critical aspect of this method is the interface compatibility conditions among neighboring subdomains. In general, this compatibility can be enforced via either iterative or strong interface boundaries. The iterative approach is easier to implement, however, it is also prone to numerical instability and slow convergence rates. Strong coupling requires devoted codes, but is faster converging and more stable than the iterative counterpart. The difference in convergence and stability of these two methods becomes more significant as asynchronous time-integration is intended. In which case, the strong coupling would be the better choice because of better stability.

In this work, significance of multi-scale simulation with respect to time integration will be outlined. The fundamentals and design of popular approached in developing asynchronous time integration schemes will be discussed. Strong and weak asynchronous time-integration methods will be compared and the mathematical basis of these methods will be reviewed. Finally, we will delve further into implementation of these algorithms in a parallel computing setting and potential inclusion in commercial CAE software such as COMSOL Multiphysics. With the flexibility and ease in coupling different physical processes in COMSOL Multiphysics, a natural step in future development would be to include physics-compatible numerical time-integrators for each sub-problem.