The Schwarz Alternating Method for Multi-Scale Coupling and Contact in Solid Mechanics

Alejandro Mota†, Irina Tezaur*

* Quantitative Modeling & Analysis Departmentt
Sandia National Laboratories
Livermore, CA 94551 USA
e-mail: ikalash@sandia.gov, web page: www.sandia.gov/~ikalash

† Mechanics of Materials Department
Sandia National Laboratories
Livermore, CA 94551 USA
Email: amota@sandia.gov

ABSTRACT

Multi-scale methods are essential for the understanding and prediction of behavior of engineering systems when a small-scale event will eventually determine the performance of the entire system. In this talk, we will discuss a novel recently-proposed [1,2] approach that enables concurrent multi-scale coupling in finite deformation quasistatic and dynamic solid mechanics by leveraging the domain-decomposition-based Schwarz alternating method. The approach is based on the simple idea that if the solution to a partial differential equation is known in two or more regularly shaped domains comprising a more complex domain, these local solutions can be used to iteratively build a solution for the more complex domain. The proposed methodology has a number of advantages over competing multiscale coupling methods, most notably its concurrent nature, its ability to couple non-conformal meshes with different element topologies and different time integrators with different time steps for dynamic problems all without introducing non-physical artifacts into the solution, and its non-intrusive implementation into existing codes.

In the first part of the talk, we will describe the formulation and theoretical properties of the Schwarz alternating method as a means for concurrent multiscale coupling in quasistatic and dynamic solid mechanics. We will show several large-scale numerical examples demonstrating the method's numerical properties and convergence based on its implementation in two massively-parallel HPC codes: Albany/LCM and Sierra/Solid Mechanics. In the second part of the talk, we will describe some more recent work in extending the Schwarz alternating method to multi-scale contact mechanics problems. Unlike the original formulation of the method for multi-scale coupling, which relies on an overlapping domain decomposition with Dirichlet transmission conditions, the contact formulation requires a non-overlapping domain decomposition with Dirichlet-Neumann or Robin-Robin transmission conditions. After describing our Schwarz contact formulation, we will demonstrate on several collision problems that our Schwarz contact algorithm is capable of simulating mechanical contact such that both energy and linear momentum is conserved and errors are less than 1%, with the number of Schwarz iterations required to resolve the problem varying depending on the stage of the collision.

REFERENCES

[1] A. Mota, I. Tezaur, C. Alleman. "The alternating Schwarz method for concurrent multi-scale coupling", *Comput. Meth. Appl. Mech. Engng.* 319 (2017) 19-51.
[2] A. Mota, I. Tezaur, G. Phlipot. "The Schwarz alternating method for dynamic solid mechanics", *Comput. Meth. Appl. Mech. Engng.* (under review).