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Peridynamic theory and multiscale methods for complex material behavior

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Simulation of complex material behavior presents huge challenges in computational science and engineering nowadays. Overcoming those challenges requires the development of novel mathematical models and computational methods. Examples of such challenges in classical solid mechanics include the characterization of the microstructure dependence of the material response, as well as the simulation of material failure and damage; similarly, the description of coupling multiscale behaviors represents a challenge in classical theories. Despite the effectiveness of classical continuum mechanics-based methods in dealing with the modeling of macroscopically relevant material properties, these approaches lack, in fact, an internal length parameter which could enable the characterization of materials and structures at different scales. Peridynamics, as a nonlocal theory, offers an alternative approach that avoids difficulties arising in classical local theories in the description of complex material behavior. Additionally, peridynamics, as a nonlocal continuum model, can be applied to coarse-grained molecular dynamics, potentially for bridging the atomistic scale to the continuum scale. Computational implementations of a peridynamic model, however, often cause huge computational cost and incompatibility with classical tractions-like boundary conditions. Hence, it is convenient to couple computational methods based on classical continuum mechanics with those based on peridynamics. In this way, small areas of a material domain, which might be affected by the presence of discontinuities, can be described with a peridynamic model, whereas the remaining parts of the domain can be represented through a more efficient local model. Moreover, multiscale coupling strategies that bridge local and nonlocal models seem to provide a solution to both the computational expense and the boundary treatment. Multiscale coupling methods, in general, refer to the class of mathematical and computational techniques for the problems that exhibit characteristic features at multiple scales. Several of these methods have been proposed in past years for the effective prediction of the material response in, e.g., composites and heterogeneous media, and have been promisingly applied to describe the contribution of nanocomponents at different scales, i.e., at nano-, micro- and macrolevel. In addition, machine learning techniques can be used in the prediction of complex material behavior. This minisymposium invites contributions on recent developments on the peridynamic theory and multiscale coupling modeling, including physics-based and machine-learning advances, for the simulation of complex material behavior.