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Peridynamic Galerkin methods for nonlinear solid mechanics

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Simulation-driven product development is nowadays an essential part in the industrial development process and there is an increasing interest in realistic high-fidelity simulation methods for manufacturing processes and material design. Thanks to their flexibility, meshfree solution methods are particularly suitable for simulating these processes, often accompanied by large deformations, variable discontinuities, or phase changes. Furthermore, in the industrial domain, the meshing of complex geometries represents a significant workload, which is usually minor for meshfree methods. Over the years, several meshfree schemes have been developed. Nevertheless, along with their flexibility in discretization, meshfree methods often endure a decrease in accuracy, efficiency and stability or suffer from a significantly increased computation time. Peridynamics, introduced by Stewart Silling in [1], is an alternative theory to local continuum mechanics for describing partial differential equations in a non-local integro-differential form. The combination of the so-called peridynamic correspondence formulation with a particle discretization yields a flexible meshfree simulation method, though does not lead to reliable results without further treatment. In order to develop a reliable, robust and still flexible meshfree simulation method, the classical correspondence formulation was generalized into the Peridynamic Galerkin (PG) methods in [2]. Conditions on the meshfree shape functions of virtual and actual displacement were presented, which allow an accurate imposition of force and displacement boundary conditions and lead to stability and optimal convergence rates. Based on Taylor expansions moving with the evaluation point, special shape functions are used that satisfy all the previously mentioned requirements by employing correction schemes. In addition to displacement-based formulations, stabilized, mixed and enriched variants can be used, which are tailored in their application to the nearly incompressible and elasto-plastic finite deformation of solids, highlighting the broad design scope within the PG methods. Extensive numerical validations and benchmark simulations were performed to show the impact of violating different shape function requirements as well as demonstrating the properties of the different PG formulations. Compared to related Finite Element formulations, the PG methods exhibit similar convergence properties. Furthermore, an increased computation time due to non-locality is counterbalanced by a considerably improved robustness against poorly meshed discretizations. In this talk, an engineering introduction with comparison to the Finite Element Method shall be given.

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