A unified strategy to mitigate the surface effect and to impose in a local way the boundary conditions in Peridynamics models

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Peridynamics is a non-local continuum theory which, thanks to the integral formulation, allows discontinuities such as cracks to initiate and propagate in solids [1]. Due to the non-local nature of the theory, peridynamic models suffer from two interrelated problems at the boundary of the domain: the "surface effect" and a difficulty in imposing the (non-local) boundary conditions. Points close to the boundary are characterised by an incomplete neighbourhood. Consequently, the most external layer of the body shows different material properties with respect to the bulk of the body resulting in an unrealistic variation of the stiffness properties. This phenomenon is known as the "surface effect" [2]. Two main approaches are used to correct it: the definition of modified bonds in the external layers of the domain or the introduction of a fictitious layer of nodes around the domain boundary [2]. Similarly, the imposition of boundary conditions is often achieved using a fictitious layer, in the case of displacement boundary conditions, or by the distribution of the external tractions as body forces applied to a certain number of nodes at or near the boundary. However, there is no general agreement on the way in which the boundary loads or displacements should be "distributed" over a finite number of layers.

We propose a unified and effective method to mitigate the surface effect and properly impose the boundary conditions [3,4]. Introducing a fictitious layer around the body provides the missing nodes, (the fictitious nodes), then multiple Taylor series expansions are used to determine their displacements as a function of the displacements of the nearest real nodes. As a result, the fictitious layer continues to deform as an outer layer of the body, significantly reducing the surface effect.

Furthermore, we introduce a new type of nodes lying on the external surface of the body, the surface nodes [5]. These nodes represent the interactions between the nodes within the body and the fictitious nodes surrounding the body. The equations of surface nodes are defined based on the concept of force flux.

Thanks to this fact, the boundary conditions can be applied directly to the surface nodes, as one would do in a local model. The accuracy of the proposed approach is assessed by means of several numerical examples (1D, 2D and 3D cases) for a state-based peridynamic model: the results are significantly improved with respect to the peridynamic model with no corrections.

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