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Solution of nonlocal diffusion-type problems in unbounded domains using a space/time approach

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Peridynamics (PD) is a recent integral-type nonlocal theory originally introduced as a reformulation of classical continuum mechanics in solids. It has proven to be particularly effective in modeling discontinuous problems such as fracture and material singularities. The PD formulation was later extended to diffusion, heat conduction and corrosion problem to make use of the advantages of this nonlocal theory in more challenging classes of problems. Particularly, the application to corrosion damage problems has attracted considerable attention in the literature. Chemical or electrochemical reactions may lead to the gradual destruction of an engineering materials in a corrosive environment. Modeling these types of problems involves a diffusion process in a coupled electrolyte/metal system with a phase-changing mechanism. The difficulty lies in capturing accurately the evolution of the moving phase boundary. Formulations to do so within the context of classical computational methods such as the finite element method exist but are often computationally expensive. PD models can largely bypass this problem as they can capture the evolution of moving interfaces fairly naturally as part of the solution process. Most of the studies relying on PD published so far are concerned with the solution of bounded domain problems. However, the application of the heat or diffusion equation on (nearly) unbounded domains is of particular interest for many scientific fields such as fluid dynamics, heat conduction, biology, finance and corrosion. In the present study, we propose a novel method of constructing Dirichlet-type absorbing boundary conditions (ABCs) in order to solve the PD diffusion equation on unbounded domains in one, two and three dimensions. To this end, we truncate the unbounded domain at an artificial boundary and impose appropriate ABCs such that the solution on the truncated domain resembles the behavior of the unbounded problem. Similarly to the nonlocal PD formulation, the ABCs are nonlocal and are updated at each time step. As the ABCs are constructed as boundary conditions of Dirichlet-type in the time domain, they neither require Laplace transforms nor special differential operators such as the perfectly matched layer method (PML). Based on a number of benchmark examples we will demonstrate the stability and accuracy of our newly introduced ABCs for long-term simulations. To our best knowledge, it is the first time that a PD model for the solution of a three-dimensional unbounded domains is proposed