Imposing Nonconforming Boundary Conditions Without Tracking the Exact Boundary Position

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Imposing Neumann boundary conditions is a classic challenge in the Material Point Method (MPM) due to material boundaries that do not conform with the background mesh as well as material boundaries that evolve throughout a simulation. Traditional approaches to impose nonconforming boundary conditions typically rely on tracking the material boundary (e.g., using massless particles) or using reconstruction algorithms to locate the boundary position for each time step. The newly developed Virtual Stress Boundary (VSB) method imposes nonconforming boundary conditions without requiring the exact boundary position. This is achieved by employing a problem transformation where the boundary traction in the original problem is transformed into an equivalent virtual stress field. Vitally, the virtual stress field imposes the exact same response within the material domain as the original problem. After completing this problem transformation, the governing equations are subsequently updated such that any boundary integrals are replaced with equivalent volume integrals. By removing boundary integrals, it is no longer necessary to track or reconstruct the position of the material boundary during the simulation. Instead, the MPM coupled with the VSB method uses a combination of particle-wise and cell-wise quadrature to solve the updated governing equations.

This presentation will demonstrate the VSB method's utility by showcasing the convergence properties for benchmark problems in 1D, 2D, and 3D. Additionally, this presentation will highlight how the VSB method may be extended to work with higher-order variations of the MPM, including the GIMP method and the B-Spline MPM.

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