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A multiscale explicit dynamics method for solid mechanics using proper orthogonal decomposition (POD)

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ABSTRACT

One of the main computational issues with explicit dynamics simulations is the significant reduction of the critical time step as the spatial resolution of the finite element (FE) mesh increases. This eventually leads to a notable increase in computational time. In this work, a multiscale time integration methodology is presented that can significantly reduce the computational cost in explicit dynamic simulations, while maintaining accuracy. The proposed method is based on a modal decomposition approach that separates the dynamics of the system into low and high frequencies. The strategy is specially designed for problems that require high spatial resolution, but whose behavior is dominated by low frequency responses over time. The proposed strategy decomposes the solution into fine and coarse scales and projects the governing dynamical equations onto these scales. The reduction of computational time obtained by this the method stems from the fact that time integration can be performed on the slow scales using a larger time step than the one corresponding to the original fine scale problem.
In this work, we use the Proper Orthogonal Decomposition method to build the slow scale space. The main idea behind proper orthogonal decomposition (POD) is to obtain an optimal low-dimensional orthogonal basis for representing an ensemble of high-dimensional data. In our proposed method, the POD space is generated with solutions from early times of the full-scale simulation and subsequently used to advance the evolution equations at the coarse scale. Basic concepts of multigrid methods are also applied in this work with the purpose of transferring information back and forth from the fine (FE mesh) and coarse (POD space) spaces. The example problems we tackled show significant decrease in computational time, without compromising the accuracy of our results.

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