Efficient data structures for data-driven mechanics

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The data-driven computing paradigm initially introduced by Kirchdoerfer & Ortiz (2016) enables finite element computations in solid mechanics to be performed directly from material data sets. From the point of view of computational effort, the most challenging task is the projection of admissible states at material points onto their closest states in the material data set. In this study, we compare and develop several possible data structures for solving this nearest-neighbor problem. We show that approximate nearest-neighbor algorithms can accelerate material data searches by several orders of magnitude relative to exact searching algorithms. The approximations are suggested by—and adapted to—the structure of the data-driven iterative solver and result in no significant loss of solution accuracy. The performance of the nearest-neighboralgorithmsare assessed with respect to material data set size at the example of 3D elasticity and elasto-plasticity test cases. We show that computations including up to one billion material data points on a single processor are feasible within a few seconds execution time.