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High-performance computing of 3D seismic wave propagation in complex structures based upon an optimized fully unstructured MPI spectral-element method

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We propagate numerically seismic waves resulting from an impact or an earthquake in large scale three-dimensional heterogeneous media that may have very complex internal structures.
For instance, we create and mesh both homogeneous and fractured models of an asteroid with strong contrasts in velocity with a highly-dispersive regolith layer at the surface using the CUBIT mesh generator developed at Sandia National Laboratories (USA).

We show how we optimized the whole algorithm on a parallel machine by reducing both communications between processors and the memory accesses inside each node. The calculations performed in each element and on the edges of each element and the loops are unrolled, which results in a significant speedup .
The unstructured meshes are partitioned using the METIS software package in order to minimize edge cuts and therefore optimize load balancing in our parallel blocking or non-blocking MPI implementations. We show the results of several simulations and illustrate the fact that they exhibit good scaling.

When meshes of very large size are required we turn to mesh decimation, which is an easy way to increase mesh resolution and is a reasonable compromise to perform very large simulations at the expense of the accuracy of the description of the geometry of the model.