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A Spectral Element Discretisation on Unstructured Triangle / Tetrahedral Meshes for Elastodynamics

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The spectral element method (SEM) defined over quadrilateral and hexahedral element geometries has proven to be a fast, accurate and scalable approach to study wave propagation phenomena. In the context of regional scale seismology and or simulations incorporating finite earthquake sources, the geometric restrictions associated with hexahedral elements can limit the applicability of the classical quad./hex. SEM.

Here we describe a continuous Galerkin spectral element discretisation defined over unstructured meshes composed of triangles (2D), or tetrahedra (3D). The method uses a stable, nodal basis constructed from PKD polynomials and thus retains the spectral accuracy and low dispersive properties of the classical SEM, in addition to the geometric versatility provided by unstructured simplex meshes. For the particular basis and quadrature rule we have adopted, the discretisation results in a mass matrix which is not diagonal, thereby mandating linear solvers be utilised. To that end, we have developed efficient solvers and preconditioners which are robust with respect to the polynomial order (p), and possess high arithmetic intensity. Furthermore, we also consider using implicit time integrators, together with a p-multigrid preconditioner to circumvent the CFL condition. Implicit time integrators become particularly relevant when considering solving problems on poor quality meshes, or meshes containing elements with a widely varying range of length scales - both of which frequently arise when meshing non-trivial geometries.

We demonstrate the applicability of the new method by examining a number of two- and three-dimensional wave propagation scenarios. These scenarios serve to characterise the accuracy and cost of the new method. Lastly, we will assess the potential benefits of using implicit time integrators for regional scale wave propagation simulations.