Achieving performance with spectral/hp element methods in heterogeneous environments: application to cardiac electrophysiology

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Patient-specific modelling of heart electrophysiology has the potential to revolutionise the treatment of cardiac rhythm disturbances. However, achieving this capability will require on-demand simulation in significantly shorter timescales than are presently possible, necessitating new numerical techniques and software capable of using modern heterogeneous environments efficiently and adapting to a range of hardware.
Spectral/hp element methods exhibit the numerical convergence properties of spectral methods while retaining the geometric flexibility of conventional finite element methods. They lead to compact data structures within each element, with the potential to make more efficient use of memory bandwidth and processor cache than linear finite element methods. Furthermore, a tensor-product structure of the elemental polynomial space leads to a number of interchangeable single-element and multi-element implementations, each with their own hardware-dependent performance characteristics at different polynomial orders. We outline a number of new numerical and implementation approaches and our developing auto-tuning strategy in the context of modelling the electrophysiology of the left atrium.

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