Towards Fast Topology Optimisation of Transient Heat Conduction Using Space-time Multigrid Methods

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Topology optimisation methods for transient problems are notoriously time-consuming due to the demand for simulating the system at every optimisation iteration. This work addresses this problem using space-time multigrid (STMG) methods which are parallelised with respect to both space and time, and transient heat conduction is considered as a test problem. A simple implementation of a space-time parallel STMG method showed that it can achieve a speedup factor of 10 relative to a space-parallel time-stepping method, but at a cost of 6 times the core-hours. This sparked an investigation into how to improve the STMG methods.

For realistic heat conduction problems, the contrast in the thermal diffusivity can easily be very large, which makes it challenging to define good semi-coarsening strategies. However, it was found that it is beneficial to define a coarsening strategy based on the geometric mean of the minimum and maximum diffusivity. Several methods of discretising the coarse levels were tested. Of these, it seemed best to use a method which averages the thermal resistivities on the finer levels. However, it is believed that this only applies in one spatial dimension.

Investigations are ongoing regarding how to improve the STMG methods further. This includes considerations about how to define the domain decomposition for the parallelisation, how many grids should be used, and whether there are any benefits to using full coarsening instead of semi-coarsening. Currently, the methodology has been demonstrated for (2+1)D problems for up to 4.2 billion degrees of freedom on 25600 cores using a space-time mesh of 1280x1280x2560 elements, for which it can perform topology optimisation in 52 minutes.