Efficient implementations of matrix-free finite element methods

Karl Ljungkvist

Uppsala University
karl.ljungkvist@it.uu.se

ABSTRACT

In this project, we are working on a matrix-free method for finite-element methods. The matrix-free method has several advantages over standard matrix-based FEM. Firstly, no matrix assembly is needed which can amount to a substantial portion of the runtime, especially for problems where frequent re-assembly is needed, e.g. non-linear or adaptively-refined problems. Secondly, the matrix-free method is more efficient on modern processor architectures such as GPUs, which require a high amount of arithmetic operations per memory access to be fully utilized. For traditional matrix-based finite-element methods, this is an issue since the sparse matrix-vector product comprising the majority of its computational work is dominated by memory bandwidth usage rather than computations, in particular for high dimensionality and element order. By using a matrix-free approach the bandwidth usage can be reduced considerably which leads to a corresponding speedup for the bandwidth-bound case.
Finally, by removing the need to keep the system matrix in memory, our matrix-free method can solve significantly larger problems, which is especially important on GPUs which have relatively small memory. In the scope of this project we are contributing code for matrix-free computations to Deal.II, which is an open-source C++ framework for finite-element computations.