HPC guided geometric optimisation of turbulent airflow

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A common challenge in the design of automotive, aerospace and industrial power systems is the routing of flow within a duct or pipe geometry. Routing, however, is often considered secondary to the design of main components and therefore subject to compromises. Further, optimal routing designs are difficult to achieve within these constraints using current engineering tools, and are often a manual process involving computer aided design (CAD) and computer aided engineering (CAE) packages. An automated tool that can effectively exploit high performance computing (HPC) resources is therefore required for the design and optimisation of flow ducts and pipes in both the conceptual design and engineering phases.

In this work, a fully automated tool chain is developed for the design and optimisation of fluid routing based on minimal pressure drop. The tool, built in C++, utilizes the ACIS geometry modelling engine and interfaces with Gambit for unstructured grid generation. A steady-state flow analysis is performed using incompressible turbulent flow via the Fluent computational fluid dynamics (CFD) package. Optimisation is controlled by genetic algorithms (GA) which have been adapted to interface with the numerical description of the geometry. Nimrod/O is used to guide the optimisation on a HPC cluster.

This paper outlines the process undertaken by the tool chain to reach an optimal pipe design, given the boundary sizes and positions in space, as well as constraints on the system. Specific case studies are presented for smooth pipe turbulent airflow. The case studies focus on using splines to define and parameterize the geometry. Finally, the paper discusses the efficiency and wider applications of the developed tool chain to more complex fluid flow design problems.