COUPLING OPENFOAM WITH FENICS FOR MULTIPHYSIS SIMULATION

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There is a trend of tight integration of Computer-aided Design (CAD) and Computer-aided Engineering (CAE) for both commercial and open source software packages. CAD platforms not only create geometry, but also provide functions of computational engineering and product life management. Meanwhile, CAE software for physical system simulation, has strengthened the geometry creation and meshing capability for a smoother engineering process. However, there are gaps for an automated engineering design/optimisation process from geometry prototyping to Computer-aided Manufacturing (CAM). In particular, the changed geometry topology, i.e. the way surfaces forming a solid geometry, will invalidate meshing and boundary condition setup in CAE, because the boundary setting is linked with volatile surface identifier integer, not the spatial coordinates. This suggests understanding geometry topology is the key to optimisation and simulation automation.

In this paper, the process of automated engineering design using Python is demonstrated, based on open source CAE modules. Built on top of the meshing functions in FEM module of FreeCAD [1], the authors developed a CFD module [2] as a graphical pre-processor for meshing, solver input setup. Open source CAE solvers such as OpenFOAM [3] (FVM) and FenicsSolver (FEM) [4], are integrated into FreeCAD, to solve multi-physics partial differential equations. The graphic user interface eases the setup of open source solver, and enables modelling complicate geometry in real-world engineering problem. User operation in FreeCAD GUI can be recorded into Python code, which assists experienced engineers in building up automatic design pipeline in a later stage. Thereby, a one-stop design process from geometry building to analysis is provided for both GUI and scripting users.

Furthermore, coupling OpenFOAM with external solver can be achieved by mesh and data exchange via files or code insertion. preCICE [5] is an emerging open source library for rapid source code integration, while MpCCI [6] is a commercial framework of file-based data exchange without modifying OpenFOAM or other external solvers. In order to be compatible with current Fem and Cfd modules of FreeCAD, the mpCCI style coupling strategy is adopted and flow-structure coupling with FenicsSolver is demonstrated. This Fluid-Structure Interaction, with large deformation nonlinear solid solver and non-Newtonian fluid solver, can be used to numerically study turbomachinery sealing, and journal bearing lubrication.

The automated process from CAD to CAM can dramatically reduce engineer's time on design prototyping and optimisation. Multiphysics solvers can be further coupled with system modelling tools, such as open standard of Modelica and Simscape of Mathworks, for multi-component system validation. In the future, artificial intelligence will be introduced into engineering design, once design automation is achieved. The target function will be a comprehensive evaluation of production cost, performance, reliability weight, etc, maintenance cost, depending on engineering sectors. For example, product design in aerospace engineering emphasizes maintenance cost, safety margin, performance for unit weight, in addition to manufacturing cost.

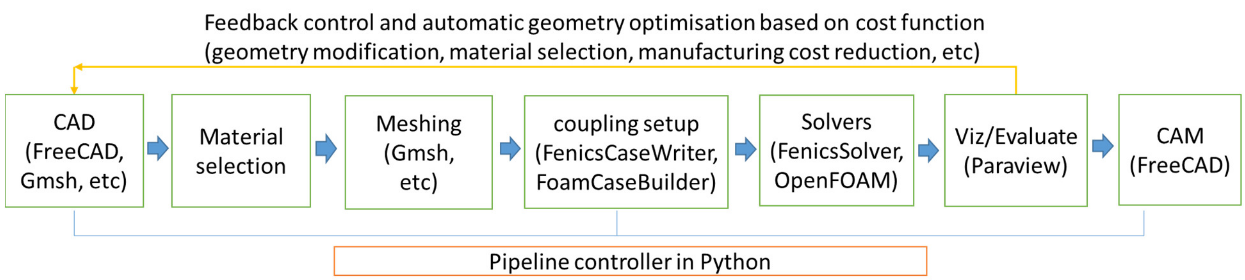

Figure 1: Pipeline of automated Multiphysics design using open source packages

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