Hybrid Mesh Validation and Visualization

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Abstract

Even though more complex to generate and adapt, hybrid structured-unstructured meshes are increasingly being recognized as a key technology to reduce unknown count and computational cost and to increase precision of CFD simulations in or around complex geometric configurations [1, 2, 3, 4, 5]. While there does not exist a single universally accepted definition of the term *hybrid mesh*, this term usually designates a discretization of a computational domain that comprises various element types either mixed together in a single set of elements or selectively used in different regions (or zones) of the computational domain and assembled in a multi-zone mesh. In the present discussion, the later definition is retained. In the context of high Reynolds number turbulent flow simulations, this type of hybrid mesh is most appropriate since it allows discretizing a computational domain using specialized highly stretched hexahedral or prismatic elements in regions where flow solution gradients are expected to be strong[6]. Such regions include, for instance, boundary layers and obstacle wakes. The remainder of the computational domain is then filled using tetrahedral elements that are simpler to generate and adapt.

In the process of automatically generating high quality hybrid meshes around complex industrial parts, automated tools for the detection of invalid element configurations and interactive tools for their visualization have become key software components to allow the rapid treatment of new geometric configurations. This paper focuses on the development of an automatic validation and interactive visualization environment specifically designed to cope with hybrid meshes. This environment comprises two distinct software components, one that fully automates geometric and topological validations on both the B-rep CAD model and the associated hybrid mesh[7], and the second that allows to interactively visualize B-rep models and general meshes comprising structured, semi-structured and unstructured regions in a single domain. Both softwares rely on a unifying data structure that allows to represent all mesh types without redundancy[8].

Key aspects of the validation software tool are its extensibility, which allows to:

- Define and run new validation algorithms both on the CAD model and on the mesh,
- Validate the consistency of the mesh in relation with the B-rep model,
- Produce automated reports on mesh quality and output diagnostics that can be interpreted by the visualization tool.

Key aspects of the visualization tool include capacities to:

- Navigate through the geometric structure and topological hierarchy of the B-rep CAD model,
- Explore mesh to CAD relationships,
- Navigate through mesh regions based on the inherent structured or semi-structured nature of the region,
- Link and simultaneously explore several regions of the mesh,
- Visually explore inconsistencies detected by the validation tool.

Taken together, these tools form the basis of specialized debugging environment for CAD and mesh for analysis purposes.

References

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