A Pseudo Cell Approach for Hanging Nodes in Unstructured Meshes

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Abstract

One of the ongoing goals of the German Aerospace Center (DLR - Deutsches Zentrum für Luft- und Raumfahrt) is the virtual design of an aircraft. This means that the aircraft's flight characteristics are determined by numerical simulation before its first flight in the real world. A key element in the aerodynamic design process is the numerical flow simulation, for which the DLR develops its next-generation CFD software code Flucs (Flexible Unstructured CFD Software) [1].

For virtual aircraft design, we have to consider the numerical simulation of complex three-dimensional transient flows. This is highly time-consuming even on today's computers. In order to reduce time, we apply mesh adaptivity to increase the mesh resolution only where it is strictly needed. However, during the mesh refinement process, hanging nodes are created along the non-conforming interfaces of large to small elements and much effort would have to be put into removing them.

Instead in this talk, we focus on how to keep the hanging nodes in the underlying unstructured mesh. Flucs uses a higher-order Discontinuous Galerkin method as well as a second-order finite-volume discretization. Discontinuous Galerkin methods especially are able to deal with very general non-matching grids containing hanging nodes. For the management of our mesh we use the Flow Simulator Data Manager (FSDM) which is open source and provides a broad library of classes for in-memory storage and parallel handling of data associated with Computational Fluid Dynamics. FSDM is already able to handle the unstructured mixed-element meshes on which Flucs is based but cannot yet store and provide information on elements with hanging nodes. We extend FSDM by so-called pseudo cells which are mesh elements that have no volume and do not contribute to computations done on the unstructured mesh in any way. We show how the pseudo cells help to provide the connectivity information of neighboring non-conforming elements for the computations of fluxes in the flow solver. The pseudo cells can even handle higher order elements with hanging nodes. To the knowledge of this author, such an approach has not yet been considered in the literature; see [2] for a related approach restricted to cubical elements.

References

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