Curvilinear mesh generation and adaption

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Rationale

In recent years, interest in high-order methods in both the scientific and industrial communities has dramatically increased, as they offer the potential to achieve higher accuracy for a given computational cost when compared to a traditional low-order approach. However, one of the most challenging issues to be overcome before these methods can be widely adopted is to develop methods for the reliable generation of high-quality curvilinear meshes which accurately represent the underlying geometry of the problem.

The generation of a curvilinear finite element mesh generally involves two steps: the generation of a coarse linear mesh, followed by a projection of the high-order surface information onto the linear mesh. For fine meshes or geometries which possess low curvature, a straightforward projection usually yields a valid mesh. However, where the curvature of the surface is high, using only a simple projection of the high-order information often leads to the generation of invalid self-intersecting elements [5]. More recent attempts to bypass this problem have involved projecting curvature at the surface into the interior of the domain using an elastic deformation procedure [3, 7]. Alternatively, one may consider an optimisation approach, whereby an iterative procedure is applied to move nodes in such a way as to reduce the number of invalid elements in the mesh, thus untangling it [6]. However, there are many topics for which these methods still need improvement, such as the generation of highly stretched boundary-layer meshes for fluid dynamics applications.

Adaptive mesh refinement for high-order curvilinear meshes is usually carried out using error estimates [2], error bounds [4], or a measure of the quality of a mesh element [1]. The literature on both error estimates and element quality metrics is not as vast for high-order curvilinear meshes as it is for linear meshes. Fast convergence of FE solutions is achieved by hp-refinement techniques, and there are plenty of open questions in the field that require focused research in order to determine an optimal technique to refine high-order curvilinear meshes.

The aim of this minisymposium is to provide a platform for discussing the latest methods related to the generation of curvilinear meshes and techniques assessing the quality and validity of generated grids.

Organization

For this minisymposium, we have selected eight talks populating two two-hour time periods. We note that there is intentionally no single application area, with talks from a range of speakers designed to encourage a broad discussion of the most recent research in the mesh generation community.

Preliminary Talk Titles and Author Information

A simple strategy for generating high-order curved finite element meshes
R. Sevilla*, O. Hassan and K. Morgan, Swansea University

High-order mesh generation for CFD
T. Toulorge*, A. Johnen, C. Geuzaine, J. Lambrechts, J.-F. Remacle, Université catholique de Louvain

An isoparametric approach to high-order curvilinear boundary-layer meshing
D. Moxey*, M. Hazan, S. Sherwin and J. Peiró, Imperial College London

On interpolation errors over curvilinear triangular finite elements
S. Sastry*, R. Kirby, University of Utah

Mixed-order, mixed-continuity finite element analysis of boundary layer flows
O. Sahni*, A. Zhang and J. Li, Rensselaer Polytechnic Institute

Development of parallel curved meshes with G1 surface continuity for high-order FEM simulations
Q. Lu*, D. Ibanez, M. Shephard, Rensselaer Polytechnic Institute

Validation and generation of curved meshes from CAD models for unstructured high-order methods
A. Gargallo-Peiró, X. Roca*, J. Sarrate and J. Peraire, Massachusetts Institute of Technology

High order unstructured curved mesh generation using the Winslow equations
M. Fortunato* and P.-O. Persson, University of California, Berkeley

Remark: * denotes the author that will present the paper.

References

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[7] Z. Q. Xie, R. Sevilla, O. Hassany, and K. Morgan. The generation of arbitrary order curved meshes for 3d finite element analysis. *Computational Mechanics*, 51(3):361–374, 2013.