Spotlights in Computational Physics and Engineering (SCoPE)

Invited lectures on:

Geometry Persistent High-Order Finite Element Mesh Generation

Zou*
xi.zou@swansea.ac.uk

Abstract

High-order finite element methods (HO-FEM) have recently received an increasing interest. In a typical simulation procedure for industrial products, it is necessary to generate a suitable mesh from computer-aided design (CAD) models with complex multiscale geometric features. This process often results in an excessively refined mesh in the vicinity of small geometric features. This is undesirable in most numerical simulations, especially those involving explicit time integration. To avoid unnecessary local refinement, the CAD model, typically represented by the non-uniform rational B-splines (NURBS), has to be manipulated, requiring a significant amount of human labour. This manipulation, including geometric cleaning and de-featuring, is a well recognised bottleneck in the industrial simulation process. The latter is of greater interest for research, because:

1. although automatic de-featuring has been investigated for several decades, it still cannot be accomplished fully automatically;
2. inconsiderate de-featuring could introduce unforeseen errors that would deteriorate the simulation results, especially for multi-physics problems.

To address the aforementioned issues, the NURBS-enhanced finite element method (NEFEM) is a promising approach. The concepts of geometric representation and solution approximation, which are coupled in the standard isoparametric/isogeometric methods, are completely separated in a NEFEM element. The geometric shape is described by the NURBS data, directly extracted from the CAD model, whereas the unknown solution is approximated by standard polynomials. Consequently, NEFEM elements not just preserve the exact geometry, but also enable the representation of complex geometric features within an element, i.e. the use of NEFEM effectively eliminates the need for de-featuring, along with the geometry discretisation error. The element size is only dependent on the user specification and not dominated by the geometric features. As a result, the time step restriction in explicit integrators is lifted, resulting in the improved efficiency of the solver. This lecture series will introduce a new scheme for generating three-dimensional meshes tailored for NEFEM. In this framework, the surface mesh is generated first from the CAD model, allowing surface elements to traverse multiple NURBS surfaces or curves, when necessary. Validity checks are performed during the generation to facilitate the further creation of volume elements. A layer of NURBS volume elements is created by growing from the surface element, and the faces of this layer are extracted as a surface mesh front. Finally, the volume elements that are interior to the domain are created based on the surface front. Validated examples will be presented to demonstrate the potential of the proposed technique. The lectures are organised as follows:

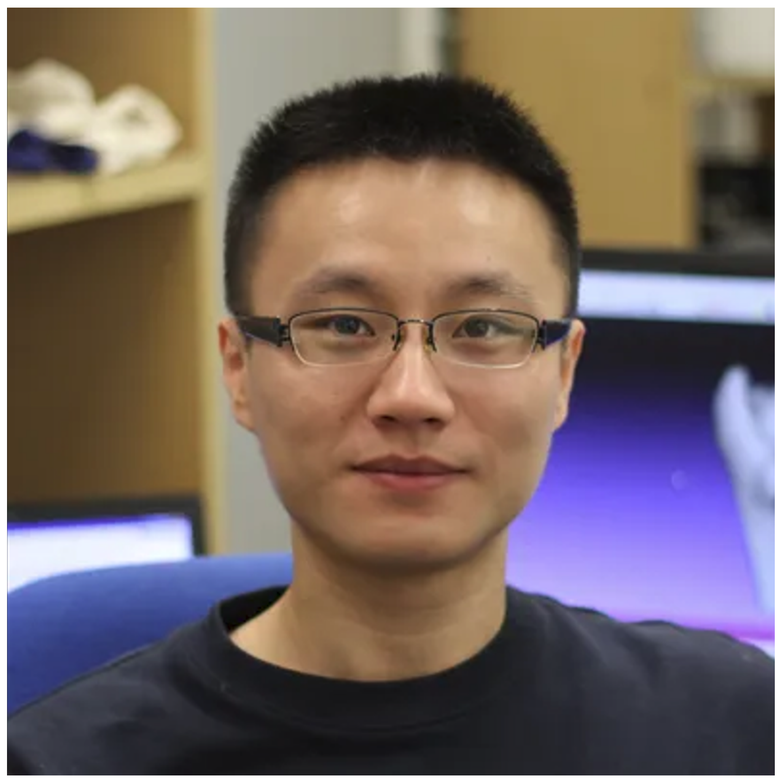
1. Introduction and motivations for generating geometric persistent meshes for HO-FEM
2. Fundamentals of NURBS-Enhanced FEM
3. NEFEM planar and surface mesh generation
4. NEFEM volume mesh generation

When and Where?

- 11.07.2024, 10:00-12:00, Maison du Nombre, MNO 1.020
- 12.07.2024, 10:00-12:00, Maison du Nombre, MNO 1.020

Invitee: Xi Zou*

XI ZOU is a Lecturer at Swansea University. He obtained his PhD degree from University of Pavia, Italy and Polytechnic University of Catalonia, Spain via the Erasmus Mundus Joint Doctorate fellowship Simulation in Engineering and Entrepreneurship Development. Prior to working at Swansea, Xi was a postdoctoral researcher at the University of Nottingham. He also worked as a Stress Engineer at Airbus China. Xi holds a Bachelor's degree in Spacecraft Design and Engineering and a Master's degree in Mechanics from Beihang University, China. He builds his expertise in finite element methods, reduced order modelling, and airframe structure analysis.



Selected Publications

- Zou X, Lo SB, Sevilla R, Hassan O, Morgan K. The Generation of 3D Surface Meshes for NURBS-Enhanced FEM. Computer-Aided Design. 2024 Mar 1;168:103653.
- Zou X, Lo SB, Sevilla R, Hassan O, Morgan K. Towards a Volume Mesh Generator Tailored for NEFEM. In: Ruiz-Gironés E, Sevilla R, Moxey D, editors. SIAM International Meshing Roundtable 2023. Cham: Springer Nature Switzerland; 2024. p. 397–418.
- Zou X, Lo SB, Sevilla R, Hassan O, Morgan K. The Generation of Tetrahedral Meshes for NURBS-Enhanced FEM. Engineering with Computers. 2024 (accepted).