Structural Engineering Seminar Series

CEE 595 S

Immersogeometric Analysis: A Geometrically Flexible Technique for CFD, Fluid-Structure Interaction, and Biomedical Applications

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Abstract:

In this presentation, I will discuss Immersogeometric Analysis, a geometrically flexible framework that has been recently proposed for the modeling and simulation of CFD, fluid–structure interaction (FSI), and biomedical applications. This novel method makes direct use of the CAD boundary representation (B-rep) of a complex design structure by immersing it into a non-body-fitted discretization of the surrounding fluid domain, thereby eliminating the challenges associated ¬¬¬with time-consuming and labor-intensive geometry cleanup and mesh generation/manipulation. This approach also effectively deals with FSI problems involving structures with complex motion that leads to large deformations of the fluid domain, including changes of topology. The first motivating applications include aerodynamic analysis of an agricultural tractor and military rotorcraft, which are directly represented using B-rep models. The key ingredients to achieving high simulation accuracy, including imposing the Dirichlet boundary conditions weakly using Nitsche's method and faithfully capturing the geometry in intersected elements, will be discussed. The second motivating application is the FSI simulation of surgical and percutaneous heart valves that are coupled to the surrounding blood flow under physiological conditions. The variational formulation for immersogeometric FSI analysis is derived using an augmented Lagrangian approach to weakly enforce kinematic constraints. A hybrid arbitrary Lagrangian–Eulerian/immersogeometric methodology, in which a single computation combines both a body-fitted, deforming-mesh treatment of some fluid–structure interfaces and a non-body-fitted treatment of others, is also developed under the same framework. Finally, I will also show that the immersogeometric capabilities can be effectively integrated with optimization methods to improve engineering designs using high-fidelity FSI analysis. This will be demonstrated using a full-scale hydraulic arresting gear system, which is used to rapidly decelerate an aircraft as it lands. Using the proposed framework, a new design of the arresting gear rotor blade is found to reduce the maximum stress and stress variance on the structure to prevent fatigue and failure.

Bio:

Ming-Chen Hsu is an Associate Professor in the Department of Mechanical Engineering at Iowa State University. He received his MS degree in Engineering Mechanics from UT Austin in 2008 and PhD degree in Structural Engineering from UC San Diego in 2012. From 2012 to 2013, he was a postdoctoral fellow at the Institute for Computational Engineering and Sciences at UT Austin before joining Iowa State University. He is the recipient of the 2019 USACM Gallagher Young Investigator Award and is listed as a Web of Science Highly Cited Researcher from 2016 to 2019. He has published over 60 peer-reviewed journal papers and serves on several national and international professional society committees on computational methods and applications. His research focuses on the development of computational fluid-structure interaction methods with an emphasis on solving engineering problems such as biomedical systems and wind energy.

Monday, October 28th, 2019   4:00 – 5:00 p.m.

1310 Yeh Student Center