WPI MATHEMATICAL SCIENCES

Kyle Dunn

PhD Candidate

Mathematical Sciences

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Stratton Hall 203

10:00am -12:00pm

Dissertation Committee:

Dr. Marcus Sarkis, WPI (Advisor)

Dr. Roger Lui, WPI (Co-advisor)

Dr. Zhongqiang Zhang, WPI

Dr. Sarah Olson, WPI

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PhD Dissertation Proposal Presentation

A Cut Finite Element Immersed Boundary Method and its Application to a Chemotaxis Model

Abstract: Originally developed for numerical analysis of cardiac blood flow, the immersed boundary method introduced in 1977 by Peskin has gained popularity in various computational applications. Peskin's method solves for the velocity and pressure of the fluid, then uses the local velocity to move the immersed boundary. Due to its growth in popularity across many applications, including cell mechanics and fluid dynamics, there has been a recent surge in effort to further study this method. Many advances have been made to better incorporate the forces applied to the fluid by the elastic structure. Specifically, we consider the finite element approach.

We will introduce a finite element method for the Stokes equations with a massless immersed membrane. We design and implement a high-accuracy cut finite element method (CutFEM) for the steady-state problem which enables the use of a structured mesh that is not aligned with the immersed membrane. Allowing the membrane to move in the time-dependent Stokes problem, we design a semi-implicit time discretization. We then prove that this semi-implicit scheme is unconditionally energy stable and illustrate this theoretical result with numerical simulations. Further advances of this method will be discussed, such as improved accuracy and preconditioning. Finally, we will apply these techniques to a chemotaxis model, combining aspects of multiple existing models and fully integrating the dynamics of the interior, exterior, and cell membrane.