WRIGHT STATE UNIVERSITY

INTERDISCIPLINARY APPLIED SCIENCES AND MATHEMATICS
PhD PROGRAM

PH.D. CANDIDATE

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DISSERTATION DEFENSE

“Efficient Numerical Methods for Chemotaxis and Plasma Modulation Instability Studies”

The oral presentation of this defense is open to all students and faculty.

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In many physical and biological problems, it is extremely difficult to conduct experimental studies to analyze the dynamical processes of interest. Therefore, modeling and numerical simulations are used to understand such complex processes. However, many of these real-world problems are governed by systems of nonlinear partial differential equations (PDEs). Here, we consider nonlinear models, namely the Keller-Segel chemotaxis equations, the model of early stage cancer cell invasion of a biological tissue, and system of equations describing the plasma modulation instability phenomenon. Obtaining numerical solutions to these models is particularly challenging and can be computationally expensive. This is due to the fact that the governing equations are highly nonlinear and their solutions are unstable, exhibit rapid variations and can develop singularities over a finite period of time. In this talk, we give an overview of these models and discuss some numerical and analytical challenges posed by these models. We employ some recently developed efficient and accurate numerical approaches for the numerical solutions of these nonlinear models. Specifically, an adaptive moving mesh finite element and finite difference methods are applied for the numerical solutions of the Keller-Segel chemotaxis model and the cancer cell invasion model in both one and two spatial dimensions. Numerical experiments are given to address the performance of the adaptive moving mesh method. On the other hand, a high order explicit pseudo-spectral method is applied for solving the system of nonlinear equations describing the wave collapses in the plasma modulation instability phenomenon. We also implement a parallel three-dimensional solver of the pseudo-spectral method to further optimize the CPU run-time. The developed solvers are shown to accurately capture the collapsed periods, which can be hard to observe in experiments, of the cavitation during the plasma modulation instability phenomenon. We present numerical examples to demonstrate the efficiency and accuracy of the proposed methods. Finally, some concluding remarks are given.