Séminaire de Dr. Rasha Al Jahdali

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Lyapunov Stability and Structure-Preserving Discretizations for Nonlinear Reaction-Diffusion Systems: From Mathematical Theory to Biological and Engineering Applications

Abstract

Reaction-diffusion equations arise in many biological, environmental, and engineering systems, where nonlinear interactions, diffusion processes, and stability properties strongly influence the long-time dynamics. In this seminar, I will present a Lyapunov based framework for analyzing and discretizing nonlinear reaction-diffusion systems to preserve the stability properties of the continuous model at the discrete level. The approach combines Lyapunov functional theory, summation-by-parts spatial operators, simultaneous-approximation-term techniques, and relaxation Runge--Kutta time integration to obtain fully discrete schemes that are consistent with the nonlinear stability structure of the governing equations. I will discuss applications to biological systems, including epidemiological models, tumor-growth and oncolytic virotherapy models, and ongoing extensions toward coral-reef response models. The goal is to demonstrate how advanced mathematical tools for nonlinear stability can yield robust, predictive, and physically meaningful simulations of complex real-world systems.

Bio of Rasha Al Jahdali

Dr. Rasha Al Jahdali is a Research Scientist in the Advanced Algorithm and Numerical Simulations Laboratory at King Abdullah University of Science and Technology (KAUST). She received her Ph.D. in Applied Mathematics and Computational Science from KAUST in 2019. Her doctoral research focused on acoustic metamaterials and the manipulation of wave propagation in complex engineered media, including the mathematical modeling, numerical simulation, and design of structures capable of guiding, focusing, trapping, and absorbing sound. Her research lies at the intersection of applied mathematics, numerical analysis, scientific computing, high-performance simulations, computational fluid dynamics, aero/hydrodynamics, acoustics, and wave propagation in complex structures.

A central theme of Dr. Al Jahdali's work is the development of robust numerical methods that translate rigorous mathematical stability principles into reliable computational tools for real-world applications. Her recent work on fully discrete Lyapunov-consistent discretizations for reaction-diffusion systems provides a systematic framework for preserving the stability properties of continuous models at the discrete level, enabling accurate simulations in areas such as epidemiology, biological transport, and oncolytic virotherapy.

Beyond theoretical numerical analysis, Dr. Al Jahdali has contributed to KAUST's high-order computational simulation capabilities, including the development and extension of the SSDC framework for entropy-stable, high-fidelity simulations of complex fluid flows. Her research connects mathematical theory, advanced algorithms, scalable software, and impactful applications in engineering, biomedical modeling, acoustics, and environmental science.

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