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RESEARCH & COLLABORATION PROFILE

KEYWORDS: Numerical Analysis, Phase-Field Models, Structure-Preserving Schemes, Multicomponent Flows, Computational Fluid Dynamics



Research Snapshot. Dr. Hwang develops accurate, stable, and efficient numerical methods for phase-field models and multi-component fluid flows. The research considers the Allen–Cahn, Cahn–Hilliard, and Navier–Stokes–Cahn–Hilliard (NSCH) equations, and derives time step conditions under which the numerical solutions preserve the maximum principle, mass conservation, and energy dissipation. The proposed methods use operator splitting, convex splitting, projection, multigrid, and Fourier/DCT solvers on regular domains, nonuniform grids, and curved surfaces. Current work develops phase-field projection methods for multi-component NSCH systems with walls and obstacles. These methods are also applied to problems in materials science, image processing, epidemiology, and computational finance.

RESEARCH EXPERTISE

- **Structure-preserving schemes:** maximum principle-preserving explicit methods, unconditionally stable operator splitting methods, and the derivation of the largest stable time step for Allen–Cahn-type equations.
- **Multi-component phase-field models:** conservative, high-order, and ternary Allen–Cahn equations, and N-component Cahn–Hilliard and Navier–Stokes–Cahn–Hilliard systems.
- **Computational fluid dynamics:** decoupled and Leray projection methods for multi-component flows, Kelvin–Helmholtz instability, droplet dynamics with obstacles, and incompressible flows on curved surfaces.
- **Fast solvers and applied modeling:** cell-structured multigrid and Fourier/DCT spectral methods, option pricing and volatility calibration, epidemic (SUC) models, and PDE-based image processing.

RECENT RESEARCH HIGHLIGHTS

- **Conservative Allen–Cahn equation (Comput. Phys. Commun. 2027):** derived a time step condition under which the fully explicit method keeps the solution within [−1, 1] and preserves the total mass in 1D, 2D, and 3D, and constructed a counterexample that violates the maximum principle beyond this bound.
- **Ternary and high-order Allen–Cahn equations (Numer. Math. Theor. Meth. Appl. 2026; Appl. Numer. Math. 2026):** derived the largest time step that preserves the discrete maximum principle for the explicit ternary Allen–Cahn scheme, and proposed an efficient hybrid method for the high-order Allen–Cahn equation.
- **Phase-field models on curved surfaces (Appl. Numer. Math. 2026; Math. Comput. Simul. 2024; Commun. Nonlinear Sci. Numer. Simul.**

POTENTIAL COLLABORATION RESEARCH

Best-fit collaborator areas: multiphase flow & CFD | materials & interface science | scientific machine learning | large-scale computation | quantitative finance

- **1. Multiphase and multi-component flows:** joint simulation of droplet dynamics, interfacial instabilities, and flows around obstacles with experimental and engineering groups.
- **2. Materials and interface science:** phase-field modeling of phase separation, solidification, and pattern formation in multi-component materials.
- **3. Scientific machine learning:** comparison and combination of physics-informed neural networks and operator learning with structure-preserving numerical methods.
- **4. Large-scale and applied computation:** parallel explicit solvers for long-time simulations, option pricing, volatility calibration, and epidemic modeling.

SELECTED RECENT PUBLICATIONS

- **Comput. Phys. Commun. 2027** — Maximum principle-preserving explicit method for the conservative Allen–Cahn equation.
- **Appl. Numer. Math. 2026** — A multigrid solver for the Allen–Cahn equation on a virtual cubic surface.
- **Numer. Math. Theor. Meth. Appl. 2026** — Maximum principle-preserving explicit scheme for the ternary Allen–Cahn equation.
- **Appl. Numer. Math. 2026** — An efficient hybrid numerical method for the high-order Allen–Cahn equation.

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REPRESENTATIVE RESEARCH FIGURES / SCHEMES

