ICMMA 2026

International Conference on Mathematical Modeling and Applications

International Conference on
"Interfacial phenomena:
bridging theory, computation, and experiments"

Abstracts

Room 603, 6th floor, Nakano Campus, Meiji University

September, 2026

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9/7(Mon.) 13:00 -13:40

On the geometry of solutions to the two-phase Serrin problem

Lorenzo Cavallina
Tohoku University

In this talk, I will discuss an overdetermined problem arising in the shape optimization problem of maximizing the torsional rigidity of composite beams made of two distinct materials separated by an interface. I will study the geometry of two-phase configurations for which this overdetermined problem admits a solution, and I will present several qualitative and geometric properties of such configurations. A particular focus will be placed on the geometry of the interface and how it affects the overall configuration's shape. Furthermore, by using the method of moving planes, I will show that the solutions exhibit no extended or narrow branches ("tentacles") away from the core. Finally, I will give a new characterization of radially symmetric optimal configurations.

2 9/7(Mon.) 14:00 -14:40

Spatial inhomogeneous diffusion based on the law of energy dissipation

Masashi Mizuno
Nihon University

We consider Fokker–Planck equations based on the law of energy dissipation with spatial inhomogeneity. This study is motivated by including temperature-dependent diffusion together with energy dissipation. First, I will explain how to derive the equation subject to the natural boundary condition. Next, we consider the long-time asymptotic behavior of the solution. In particular, we will show exponential decay of the dissipation. Finally, we will discuss the interaction between spatial inhomogeneity and the decay rate of the dissipation from the viewpoint of numerical simulation.

This talk is based on joint work with Kouta Araki (Nihon University).

3 9/7(Mon.) 15:00 -15:40

Time periodic solutions of mean curvature flow equation with bilateral periodic obstacles

Takeshi Ohtsuka
Tokyo University of Science

In this talk we consider a level set equation for the interface motion by mean curvature with obstacles, which is of the form

$$\min\left\{\max\left\{u_t + F(\nabla u, \nabla^2 u), u-\phi\right\}, u-\psi\right\} = 0 \quad \text{in } (0,\infty)\times\mathbb{T}^n. \tag{1}$$

where $F(p,X) = -\mathrm{tr}\left\{\left(I - \frac{p\otimes p}{|p|^2}\right)X\right\}$. Under suitable assumptions for obstacles ψ, ϕ and initial data u_0, (1) has a unique viscosity solution $u \in C([0,\infty)\times\mathbb{T}^n)$ satisfying $u(0,x) = u_0(x)$ and $\psi(t,x) \le u(t,x) \le \phi(t,x)$ for $(t,x) \in (0,\infty)\times\mathbb{T}^n$.

From numerical simulations of (1), one can find that the interface described by the level set of u exhibits periodic motion under periodically moving obstacles. The aim of this talk is to construct a periodic viscosity solution to (1), which will be corresponding to the asymptotic behavior of global solution u, under the assumption $\psi(t+T,x) = \psi(t,x)$, $\phi(t+T,x) = \phi(t,x)$ for $(t,x) \in \mathbb{R}\times\mathbb{T}^n$.

Our strategy is considering a perturbed equation of (1), which is of the form

$$\min\{\max\{u^\varepsilon_t + \varepsilon u^\varepsilon + F(\nabla u^\varepsilon, \nabla^2 u^\varepsilon), u^\varepsilon - \phi\}, u^\varepsilon - \psi\} = 0 \quad \text{in } (0,\infty)\times\mathbb{T}^n. \tag{2}$$

Then, we find a unique time-periodic viscosity solution to (2) with a uniform bound of u^ε, u^ε_t and Du^ε. Consequently, we obtain the periodic solution to (1) by limiting procedure. This is a joint work with K. Ishii and S. Koike.

4 9/7(Mon.) 16:00 -16:50

Solving Hamilton-Jacobi equations by minimizing residuals of monotone discretizations

Yen-Hsi Richard Tsai
The University of Texas at Austin

We establish a well-posedness and error-estimation framework that solves Hamilton–Jacobi equations by minimizing the least-squares residual of monotone finite-difference discretizations. This approach also applies naturally to second-order elliptic and parabolic problems.

We prove that, under suitable monotonicity conditions, every critical point of the residual loss functional is the unique global minimizer and coincides with the solution of the discrete scheme.

We derive *a posteriori* error estimates that bound the approximation error by the magnitude of the residual, with explicit, computable constants, and extend the full analysis to time-dependent problems with implicit discretization of the time derivatives.

A spectral analysis of the linearized system shows that the condition number scales as $O(\Delta x^{-1})$ for proper schemes, and as $O(\exp(\Delta x^{-1}))$ under a uniform ellipticity condition on the discretization. We also show that, when the numerical scheme is consistent with a second-order elliptic PDE, then, the condition number scales as $O(\Delta x^{-2})$. These results quantify the increasing difficulty of solving the optimization problem on finer meshes, and motivate a progressive multi-level warm-start strategy using Artificial Neural Networks.

Combined with the convergence theorem of Barles and Souganidis for monotone and consistent schemes, our results guarantee that the solutions obtained converge to the unique viscosity solution as the mesh is refined.

Numerical experiments demonstrate the scalability of the approach to high-dimensional Eikonal equations, level-set problems, and Hamilton–Jacobi–Isaacs equations with genuine second-order diffusion arising from stochastic differential games.

5 9/8(Tue.) 13:30 -14:10

A renormalization group theory of axisymmetric bubble breakup inspired by recent studies on non-axisymmetric self-similar dynamics

Ko Okumura
Ochanomizu University

Using an original experimental setup in which a disk entrains air into a viscous liquid in a confined geometry, we recently identified several distinct non-axisymmetric self-similar dynamical regimes of the air–liquid interface [1–4]. These self-similar regimes suggest a deep analogy with critical phenomena. To explore this analogy, we apply a renormalization group (RG) theory for deterministic partial differential equations (PDEs) developed by mathematicians [5] to the classical problem of axisymmetric bubble breakup, in which viscosity competes with capillarity [6]. We show that self-similar solutions arise as RG fixed points and are shared by a broad class of PDEs, including highly nonlinear equations, which therefore constitute a universality class, and that stability analysis uniquely selects the experimentally observed solution. We further show that both self-similarity and universality emerge from the scale invariance of governing equations even in the presence of irrelevant terms [7]. We will also discuss [8] how a field-theoretic RG theory for a nonlinear diffusion equation, based on renormalization techniques from quantum field theory, can be unified with the mathematicians' RG theory.

[1] Hana Nakazato, Yuki Yamagishi, and Ko Okumura, Phys. Rev. Fluids, 3:054004, 2018.
[2] Hana Nakazato and Ko Okumura, Phys. Rev. Research, 4(1):013150, 2022.
[3] Shoko Ii and Ko Okumura, under revision.
[4] Ikumi Yoshino and Ko Okumura, Phys. Rev. Research 7, 043346 (2025).
[5] J. Bricmont, A. Kupiainen, and G. Lin, Commun. Pure Appl. Math, 47:893, 1994.
[6] J. Eggers and M. A. Fontelos, Singularities: formation, structure, and propagation, Cambridge Univ. Press, 2015.
[7] Ko Okumura, Sci. Rep., 15:34507, 2025.
[8] Ko Okumura, Physica A: Stat. Mech. Appl. 687 (2026) 131362; ibid., 688, 131406 (2026).
[9] N. Goldenfeld. Lectures on Phase Transitions and the Renormalization Group. Addison-Wesley Pub., 1992.

6 9/8(Tue.) 14:10 -14:50

How does hydration water relate to the properties and functions of soft matter and biomolecules?

Mafumi Hishida
Tokyo University of Science

Soft matter and biomolecules, such as surfactants, polymers, lipid membranes and proteins, exhibit their functions by forming various self-assemble structures in water. We investigate how the hydration water is involved in these self-assembly and functions. By employing a specialized spectroscopic technique known as THz spectroscopy, we have been able to capture in detail changes in the mobility of water within these systems and investigate the relationship between changes in water dynamics and the self-assembly and functionality of soft matter and biomolecules. The results have revealed that the mobility of the surrounding water and its hydrogen-bonding structure are deeply involved in various physical properties, including lipid membrane fusion, protein stability, enzyme activity, and the thermal responsiveness of polymers.

7 9/8(Tue.) 15:10 -15:50

Pair-induced active motion of two different species

Yutaka Sumino
Tokyo University of Science

Newton's third law imposes action-reaction symmetry that balances internal forces. Under nonequilibrium conditions, however, effective interactions can violate this symmetry, allowing active motion to emerge through pairing of different species. In this presentation, I introduce two examples of such pair-induced active motion: a camphor-washer system driven by the Marangoni effect and a bidisperse colloidal system driven by electrohydrodynamic (EHD) flows.

In the camphor-washer system, floating camphor and washer particles interact through attractive lateral capillary forces and repulsive Marangoni forces. Because the Marangoni interaction is asymmetric between the two particle species, the pair exhibits self-propelled motion. Depending on the temporal dynamics of the camphor concentration field, the motion changes from straight to circular trajectories. By varying the viscosity of the aqueous phase, we induce this transition and show that it is consistent with a pitchfork bifurcation.

In the bidisperse colloidal system, electric fields generate EHD flows around polystyrene particles, producing attractive interactions. Since the flow strength depends on particle size, interactions between differently sized particles become asymmetric, resulting in pair propulsion. I will discuss how these nonreciprocal pair interactions give rise to collective behaviors in many-particle systems.

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9/8(Tue.) 15:50 -16:30

Energetics-Based Modeling for Diffusiophoretic Motion Coupled with Droplet Deformation

Hiroyuki Kitahata
Chiba University

Self-propelled droplets floating on a liquid surface provide simple physicochemical systems exhibiting self-propulsion. A droplet containing surface-active compounds releases chemicals to the surrounding interface, lowering the local surface tension. Even a circular droplet can lose stability and begin spontaneous translational motion. For a deformable droplet, the concentration field, motion, and shape are coupled to one another. We construct a two-dimensional model for this coupling using an energetics-based approach. The droplet shape is expressed by Fourier modes, while the emitted chemicals obey reaction-diffusion dynamics. Variations of a free-energy functional, including surface and line energies, yield the equations for translation and deformation. Restricting the shape dynamics to the second Fourier mode, corresponding to elliptic deformation, we derive a reduced ODE model and analyze its bifurcation structure. Numerical simulations of the PDE model and stability analysis of the reduced ODE model reveal three stable states: an immobile circular droplet, an immobile deformed droplet, and a mobile deformed droplet, which travels along its minor-axis direction. Near the onset of motion and deformation, the reduced model reproduces the PDE results and clarifies how droplet shape and self-propulsion are coupled [1].

[1] H. Kitahata, Y. Koyano, Y. Kobayashi, M. Nagayama, Phys. Rev. E 113, 035408 (2026)

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9/8(Tue.) 16:40 -17:30

The dead-water phenomenon: theory, experiments and simulations

Julien Dambrine[1],
Johan Fourdrinoy[2], Madalina Petcu[1], Morgan Pierre[1], Germain Rousseaux[2].

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[2] *Team Curiosity, Institut Pprime, CNRS, Université de Poitiers, ISAE-ENSMA*

What could cause a ship sailing through a deep-water fjord to suddenly experience a spectacular drag for no apparent reason? This is precisely the observation reported by Nansen in his book Farthest North, published in 1897, which recounts his polar expedition aboard the ship Fram.

The most common explanation lies in the fact that fjords are characterized by the presence, at a certain depth, of a more or less sharp interface—known as a pycnocline—separating a layer of fresh (less dense) water from a layer of salt (denser) water. This is how Ekman interpreted the phenomenon in 1904, reproducing it in the laboratory and observing how a ship could generate a wave at the pycnocline. More recent experimental work (Mercier et al. 2011, Medjdoub et al. 2019, Fourdrinoy et al. 2020) has refined our understanding of the phenomenon. As part of a multidisciplinary collaboration between physicists and mathematicians from the CNRS and the University of Poitiers, we propose a wave–ship interaction model based on a linear (yet fully dispersive) theory of internal waves. An analysis of this model, complemented by simulations and compared with experiments, has allowed us to disentangle the respective contributions of transient effects and wave-radiation effects.

10 9/9(Wed.) 10:00 -10:40

The Surface-Constrained Level Set Method for Multiphase Interfacial Motions

Elliott Ginder
Meiji University

The level set method is one of the most power tools of the applied mathematician. It allows one to mathematically express the evolution of shapes and is used throughout the sciences to model phenomena ranging from the free-surface motion of fluids, to the processing of digital images. Nevertheless, the level set method has largely been limited to modeling the evolution of shapes in euclidean spaces. This research extends the level set method to the multiphase surface-constrained setting where surfaces are defined by point clouds.

11 9/9(Wed.) 11:00 -11:40

A Stabilized Dual-SAV Parametric Finite Element Framework for Constrained Planar Curve Flows with Tangential Mesh Regularization

Koya Sakakibara
Kanazawa University

Parametric finite element approximations of constrained geometric flows must address geometric stiffness, mesh degeneration, and nonlinear global constraints. This talk presents a stabilized dual-SAV framework for closed planar curves. Separate scalar auxiliary variables are introduced for the physical geometric energy and an artificial mesh regularization energy. By coupling the mesh force only to tangential motion, the method redistributes mesh points without adding an artificial normal driving force. A frozen-metric semi-implicit discretization with zero-order stabilization yields linear spatial response problems and discrete dissipation estimates for the modified geometric and mesh SAV energies. Nonlinear global constraints are treated by algebraic block reduction: after a small number of symmetric positive-definite response solves, only a (K+1)-dimensional nonlinear system remains for K constraints, independently of the mesh size. Numerical examples include curve shortening, area-preserving curve shortening, curve diffusion, and constrained Helfrich-type flows, demonstrating temporal accuracy, accurate constraint enforcement, modified-energy dissipation, and improved mesh quality.

12 9/9(Wed.) 13:30 -14:10

Fire Spread Dynamics in the 2025 Ofunato Wildfire

Kazunori Kuwana
Tokyo University of Science

Wildfire spread is strongly controlled by fuel moisture, wind, and terrain, and manifests through distinct modes such as surface fires and crown fires. In humid temperate climates, however, large-scale wildfires are relatively rare and remain less documented than those in fire-prone, summer-dry regions such as western North America and Mediterranean Europe. This presentation examines the 2025 Ofunato wildfire in Iwate Prefecture, Japan, which became the country's largest wildfire in over half a century under unusually dry conditions. We highlight the rapid spread that occurred shortly after ignition on February 26, 2025, the development of extensive crown fires, and the associated spotting that promoted spread across complex terrain. These findings shed light on how anomalous fuel dryness and strong winds can overcome typically moist conditions to produce high-intensity wildfires in humid temperate environments, with implications for wildfire risk assessment and emergency planning.

13 9/9(Wed.) 14:30 -15:10

A Geometric Model of Nanoparticle-Catalyzed Nanopore Formation on Ceramic Substrates

Koichi Sudoh
The University of Osaka

Metal nanoparticles can form nanopores on ceramic substrates during high-temperature annealing. Nanopore formation is driven by nanoparticle-catalyzed sublimation of the substrate. Based on insights gained from previous experiments, we present a simple geometric model describing the morphological evolution during nanopore formation. In the model, we assume that the nanoparticle and substrate surfaces evolve through surface diffusion, the nanoparticle/substrate interface evolves through interface diffusion, and substrate sublimation occurs in the vicinity of the triple line. Numerical simulations of the proposed model demonstrate that it successfully reproduces the experimentally observed nanopore formation process and provides insight into the mechanisms governing morphological evolution.