

OIST-Keio Showcase talk Series 8

Science meets Society: Twist, Flow, and Instability
Abstracts

TALK SESSION 1 "Analysis and Design of Structures and Fluid Flows"

Dr. Koji Fukagata	Professor, Keio	Applications of CNN autoencoders to fluid mechanics problems
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Application of machine learning is currently one of the hottest topics in fluid mechanics. In our research group, we have started a research project to construct a machine-learning-based nonlinear feature extraction method for an advanced design of flow control. In this talk, we first introduce the structure of a convolutional neural network (CNN)-based autoencoder and compare with a conventional linear method. Then we introduce some examples on the application of for temporal prediction of a turbulent flow field and extraction of low-dimensional nonlinear modes for flow around a bluff body accompanying vortex shedding. We also introduce our recent attempt on its use for an advanced design of flow control.

Dr. Eliot Fried	Professor, OIST	From underconstrained linkages to Möbius bands: Isometric, isoenergetic pathways of eversion
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We connect the kinematics of underconstrained rings of rigid links with isometric, isoenergetic eversions of elastic Möbius bands. Our starting point is the family of Möbius kaleidocycles, closed chains of $n \geq 7$ identical links joined by revolute hinges. The twist angle between successive hinges must assume an n -dependent critical value to achieve closure with a single internal degree of freedom. At this value, the linkage admits only one mode of motion: an eversion. Closure is not possible for subcritical angles, and supercritical angles yield multiple internal degrees of freedom, so that a Möbius kaleidocycle is underconstrained for $n \geq 8$. As $n \rightarrow \infty$, the Möbius kaleidocycles approach a ruled Möbius band with three half-twists and three-fold rotational symmetry. Guided by this understanding, we study the inverse problem of identifying stable isometric deformations of circular helicoids to Möbius bands and characterizing their periodic shape-preserving eversions. For an elastic band with bending-energy density that is an even function of the mean curvature, an isometric eversion requires no external work. A nonuniform finite-difference scheme applied to the midline of these bands generates families of linkages that preserve a single internal degree of freedom under arbitrary link rearrangements. Through this synthesis, we establish correspondences between

TALK SESSION 2 "Multiphase Fluid Dynamics"

Dr. Satoko Fujioka	Associate Professor, Keio	A novel design for multiphase flow reactors enabling continuous chemical processes
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Technologies for process intensification (PI) are actively being developed to dramatically enhance the efficiency and miniaturization of chemical processes. Our research group focuses on developing multiphase flow reactors, such as slug flow reactors and oscillatory baffled reactors, to enable highly efficient continuous processes.

In particular, liquid-liquid slug flow—where two immiscible fluids flow alternately in a narrow channel—is known to exhibit high heat and mass transfer performance. This is attributed to the strong mixing effect from internal circulation within the elongated droplets (slugs).

While many processes utilize this phenomenon, few studies have directly evaluated how operating conditions or fluid properties affect this internal circulation. In this talk, we present our findings on the direct evaluation of the velocity distribution within these slugs using PIV analysis. Based on these

Dr. Dan Daniel	Assistant Professor, OIST	An Electrifying Farewell: How Evaporating Drops Charge and Explode
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When a drop evaporates, it is easy to think of it as a purely thermal and mass-transfer process. In reality, subtle electrohydrodynamic phenomena can transform its quiet demise into a highly charged and sometimes violent event. In this talk, I will explore how sessile water drops spontaneously acquire and redistribute electrical charge during evaporation, leaving behind intricate bipolar surface charge patterns [1]. Under certain conditions—such as when contact-line pinning is eliminated—the shrinking drop can accumulate enough charge to approach its electrostatic stability limit. At this point, electrostatic repulsion overwhelms surface tension, triggering Coulombic explosions and fine spray ejection [2, 3]. These findings reveal evaporation as a rich playground for soft matter physics, where thermal, hydrodynamic, and electrostatic forces converge to produce surprising dynamics.

[1] N. Singh, A.D. Ratschow, N. Aslam, D. Daniel, "Bipolar surface charging by evaporating water droplets," <https://arxiv.org/abs/2508.08884>

[2] M. Lin, P. Zhang, D. Daniel, "Exploding droplets on lubricated surfaces," <https://doi.org/10.21203/rs.3.rs-4486603/v1>

[3] <https://www.youtube.com/watch?v=F0F8P23DUo0>

TALK SESSION 3 "Geophysical Fluid Dynamics"

Dr. Norihiko Sugimoto	Professor, Keio	Spontaneous gravity wave radiation in geophysical fluid
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Inertia-gravity waves (IGWs) play important roles in both the atmosphere and ocean through their momentum fluxes. They drive the middle atmosphere's circulation and make a pathway for energy toward small scales where dissipation can occur in the ocean. Their small scales are such that they need to be parameterized, requiring a good fundamental understanding of their dynamics, from their sources to their dissipation. A persistent difficulty has concerned non-orographic waves generated by the dynamics near jets and fronts, which is tied to the difficult and fundamental issue of gravity wave generation from balanced motions, or 'spontaneous generation'. In this talk, we will present numerical simulations of spontaneous gravity wave radiation in f-plane shallow water and continuously stratified systems and discuss its mechanism and impact on the atmosphere and ocean.

Dr. Amin Chabchoub	Associate Professor, OIST	The Hydrodynamics of Extreme Wave Events
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Extreme ocean waves, often referred to as rogue or freak waves, represent some of the most hazardous and scientifically fascinating phenomena in hydrodynamics. This talk will explore the fundamental mechanisms underlying their formation, focusing on the competition between linear superposition and nonlinear modulation instability. By bridging theoretical modeling, numerical simulations, and laboratory experiments, we will discuss how these two frameworks contribute to our understanding of wave energy focusing and the onset of extreme sea states. Special attention will also be given to the hydrodynamic loading on marine structures during such events, highlighting challenges in prediction and design resilience. Finally, perspectives will be offered on current strategies for disaster risk mitigation, including early-warning methodologies and the development of smart structures capable of absorbing wave energy.