MECHANICAL ENGINEERING GRADUATE STUDENT SEMINAR SERIES

Sunday, Dec. 6th , 2026 at 12:30 p.m., D. Dan and Betty Kahn Building, 1

Learning in floating matter: self-assembled conducting particle networks trained by thermocapillary flows

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Artificial intelligence relies on computing hardware that consumes considerable energy, partly because information is stored in one place and processed in another. In the brain, learning happens where information is stored, through local changes in the strength of the connections between neurons. Physical learning is an emerging field that applies this principle to physical systems, in which each component adjusts its own properties based only on the signals it experiences, without a central computer. In this seminar I will present an approach in which such a learning network is not fabricated, but builds itself. The system consists of small conducting particles floating on water. Each particle bends the water surface around it, and when two particles come close, these surface deformations overlap and pull or push the particles, the same effect that makes cereal clump together in a bowl of milk, known as the "Cheerios effect." By designing the shape, weight and wetting of the particles, these capillary forces can be tuned so that the particles assemble into connected networks through which electric current can flow.

I will first present our theoretical model for the water surface around a single non-circular particle, obtained by solving the Young-Laplace equation with a domain-perturbation method, and compare it with laser-scanning measurements of the surface shape, which show good agreement. Next, I will describe how such a network could learn. Current flowing through the network heats it (Joule heating), and since surface tension decreases with temperature, uneven heating creates surface flows, known as Marangoni flows, that move the particles and change their connections. As a first step, I will show an experiment on a Janus floating particle that moves away from a locally heated region and present a model of it. Then, I will present our experimental system we are currently building to test Contrastive Hebbian Learning (CHL), a rule inspired by the way connections in the brain are strengthened. It consists of two adjacent cells filled with floating Janus particles and three electrodes: input on the left, output in the middle, shared by both cells, and ground on the right, so the output voltage is set by the balance between the conductances of the two cells. Each training step compares two situations. First, a voltage is applied only to the input electrode, and the free output voltage is recorded. Then the output electrode is also gently pushed toward its desired value. The difference in current, and therefore in heating, between the two situations drives Marangoni flows that rearrange the particles and change how well each cell conducts. By tuning the voltages, step by step, the free output voltage moves toward its target. Such self-assembled networks may lead to computing materials that form and learn on their own, rather than being manufactured.

Note: the seminar will be given in English

Seminars Coordinator: Prof. Steven Frankel.