SCHOOL OF INFORMATICS AND COMPUTING

Intelligent Systems Engineering Colloquium Series

William Uspal

Tuesday, April 18, 2017

1:30 PM

Indiana Memorial Union

Sassafras Room

Artificial Microswimmers in Confined and Flowing Environments

Abstract: Autonomous microscopic agents moving through confined, liquid-filled spaces are envisioned as a key component of future lab-on-a-chip and drug delivery systems. Chemically active Janus particles offer a potential experimental platform for the realization of such agents. These particles locally harvest energy by catalyzing, on a fraction of their surface, the decomposition of a fuel molecule present in the surrounding solution. The resulting self-generated chemical gradients drive flow in the solution and, therefore, directed "swimming" motion of the particles.

These simple microscopic particles cannot store or process information internally. Instead, we consider how goal-directed and adaptive behavior can emerge from the physiochemical interaction of a particle and its environment. In particular, we develop a theoretical model of a particle and the self-generated chemical and hydrodynamic fields surrounding it. These fields, which drive particle motion, also probe, and are modified by, the surrounding environment, creating a feedback loop between sensing and motility. This feedback loop can be tailored through the design of the particle, e.g., surface chemistry and geometry.

Guided by this insight, we show that certain designs of particle can sense, bind to, and swim along a confining surface [1]. Further, we show that the particles can sense and respond to changes in the material composition of the surface [2]. For instance, particles can be designed to follow chemically patterned "roads." Finally, we consider active particles in external flow fields. We find that when the particles swim near a surface, they can exhibit a rich and surprising orientational response to flow. For instance, they can align against the flow direction and swim upstream ("rheotaxis"), or align perpendicular to the flow direction and swim across fluid streamlines [3]. We present experimental observations of the predicted cross-stream migration [4]. Overall, these various behaviors illustrate the "intelligence" that can be evoked from artificial microswimmers, and could be harnessed for applications.

[1] W. E. Uspal, M. N. Popescu, S. Dietrich, M. Tasinkevych, Soft Matter 11, 434 (2015).
[2] W. E. Uspal, M. N. Popescu, S. Dietrich, M. Tasinkevych, Phys. Rev. Lett. 117, 048002 (2016).
[3] W. E. Uspal, M. N. Popescu, S. Dietrich, M. Tasinkevych, Soft Matter 11, 6613 (2015).
[4] J. Katuri, W. E. Uspal, J. Simmchen, A.-M. Lopez, S. Sanchez, submitted.

Biography: William Uspal is a postdoctoral associate at the Max Planck Institute for Intelligent Systems in Stuttgart, Germany, in the department "Theory of Inhomogeneous Condensed Matter". He is currently developing models of how micro- and nanoswimmers behave collectively and in complex environments. He received a Ph.D. in Physics from MIT (2013) for his work on designing microparticles that self-organize when driven by flow through microchannels. Earlier, he received a B.Phil. degree in Engineering Physics, Mathematics, and Philosophy from the University of Pittsburgh (2007), where he worked on simulations of membranes and vesicles. His other research interests include single-molecule polymer physics and field-responsive suspensions.

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