Thrust 4. Active Soft Materials towards Bio-functional Nano-Robotics

Xuanhong Cheng (MSE/BioE), Subhrajit Bhattacharya (MEM), Angela Brown (CBE), Javier Buceta (BioE), Manoj Chaudhury (CBE), James Gilchrist (CBE), Anand Jagota (CBE/BioE), Dmitri Vezenov (Chem), Edmund Webb (MEM), X. Frank Zhang (MEM)

Nanorobotics has been envisioned for more than 50 years, and holds the potential to revolutionize manufacturing, biomedicine and many other fields. If we define robotics as the development of a system to accomplish arbitrarily defined tasks from classes such as building structures, delivering material, or modifying processes then, for robotics at the nano-and micro-meter scales, one needs active programmable agents at about the same length scale. The most striking example of *soft robotics* is the development of a human from a single fertilized egg in a most complex, self-actuated, programmed, and environmentally sensitive manner. Even in homeostasis, biology has myriad interacting systems of interacting biomolecular agents that carry out a variety of physiological functions such as wound healing, immunological response, and selective delivery of therapeutic molecules. The active agents, i.e. the robots, are nearly universally bio-macromolecules that function by large conformational changes and by molecular recognition. Complex living systems routinely carry out sequences of actions typical of macroscopic robots: sensing, navigation, locomotion, manipulation, and communication. Remarkable individual demonstrations notwithstanding, very little of this function has been deliberately harnessed by scientists and engineers to form what would be recognized as a complete scalable robotic system accompanied by a modeling and control framework.

The faculty team of this thrust proposes to bring robotics to the micro- and nano-scale, for the first time as an entire system. This goal requires development of a comprehensive framework, including specific components for demonstration of canonical tasks and an accompanying modeling, motion planning, and optimization methodology. The team has identified two types of autonomous robotic agents – macromolecules at the nano-scale and micro-droplets/rods/particles at the micro-scale – along with a network of channels on which they operate. The accompanying modeling, motion planning, and optimization framework is incorporating the physics of stochastic dynamics, which is an inherent and distinguishing feature of robotics at this scale. Because this research addresses basic issues such as Boolean decisions by autonomous agents, and optimal functioning of connected networks, there is considerable scope for additional new intellectual impact. For example, an agent making a decision at network junctions of the side branches is an example of Boolean bistability. As another example, neural networks form the backbone of biological intelligence. The team strives to achieve similar intelligence in a physical network, which could shed light on the functioning of one of the most used and powerful tools today in the field of Artificial Intelligence. Beyond fundamental explorations, this thrust could also impact a wide spectrum of applications and can be adapted to different proposal calls. The thrust is built on Lehigh's long standing strength in colloid, soft matter and interfacial sciences, as well as recent growth in the area of bio-functional materials and devices.