Towards Autonomous Soft Robots: Materials, Design Architectures, & Modeling

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Progress in soft lithography, additive manufacturing, biohybrid engineering, and soft materials integration have led to extraordinary new classes of soft-matter sensors, circuits, and actuators. These materials represent the building blocks of soft machines, robots, and bio-inspired systems that will exhibit the rich multifunctional versatility and robust adaptability of soft biological organisms. While there are key challenges in materials and manufacturing that remain to be addressed, further progress in soft robotics now depends on accomplishing a new set of goals: systems-level materials integration, untethered functionality, and robot autonomy. In this talk, I will focus on this latter set of challenges and the new fundamental questions that emerge when exploring the interface of soft multifunctional materials, rigid microelectronics, and robot mobility. In particular, I will report efforts by my lab to create an untethered soft robot capable of walking in a variety of environments, including rocky terrain and confined spaces. I'll also present recent work on mechanically robust and self-healing electronics that can withstand extreme loading and damage. When used as internal circuit wiring within an electrically-powered soft robot, such materials enable autonomous response to tearing, puncturing, or material removal – damage modes that would be catastrophic for most other soft-bodied robots. I will close by highlighting ongoing efforts to create new computational tools for modeling the motion and surface interactions of limbed soft robots. Based on continuum mechanics, finite element analysis, and emerging techniques in computer graphics, these tools represent another critical requirement for soft robot autonomy by potentially enabling on-board computational intelligence and adaptive decision making.