Grand Challenges in Biologically Inspired Structural and Material Systems

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Due to the advances in materials, electronics, and system integration technologies, structural dynamics and control researchers in various disciplines have been investigating the feasibility of creating adaptive structural and material systems. The ability to concurrently achieve distributed large stroke and force actuation, autonomous and significant property change, self-sensing, self-reconfiguration, and self-healing has been the unreachable dream of the adaptive materials and structures researchers for the past 20 some years. None of the current material systems can effectively and simultaneously address these issues.

It has been recognized that in order to achieve significant advances in this field, the adaptive structure researchers have to conduct more cross talks with researchers in various other scientific disciplines, such as biology, chemistry, molecular and nano science. Various biologically-inspired adaptive structure concepts have been investigated, emulating the physiological behaviors of animals. On the other hand, live plant tissues are known for their excellent strength, stiffness, and toughness per unit density and their capability to sense damage, transport mass, regulate temperature, and self heal. Moreover, these characteristics can vary significantly over time and position in a single plant, as dictated by global and local stimuli. Thus, plants have much to offer in terms of basic materials design and actuation/sensing approaches that could cause a significant technology leap for future multifunctional adaptive structures.

To develop such a new breed of bio-inspired adaptive structural systems, there are many technical challenges to overcome. First, we need to develop better understandings of the plant cell walls and the orientations of plant cells in nastic structures that can provide the most effective and efficient actuations. We should further examine the cellulose deposition in plant cells and utilize such knowledge to advance the bio-sensing, self-reconfigurable and self-healing abilities of future adaptive structures. Finally, system integration is also extremely important -- we envision that artificial cells will be engineered, fabricated, miniaturized and assembled to form a topology resembling a plant-like, fluidic circulatory network for sensing and actuation, for energy harvesting, for thermal management, for delivering power, for self-healing in the event of damage, and as a means of fluidic actuation for shape change.