Grand Challenge Research on Bioactuators – Building and Control of Synthetic Muscles

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Through the process of refined evolution, skeletal muscles have distinct advantages over known actuation technologies derived from modular construction of energy dense compliant fibers with selective efficiency, high power-to-weight ratio, integrated sensing, augmented flexibility, and extended durability. They achieve their function through integrated actuation modules and distributed sensors. By configuring their fundamental actuating modules in parallel, skeletal muscles offer increased power, but by configuring them in series, they offer greater positional range.

Grand challenge research on bio-inspired actuators investigates recreating this modularity with smart material component actuators, and seeks a transformative, flexible, self sensing, and reconfigurable synthetic muscle package. Hardware will be controlled by software coded to detect different initial configurations and real time partial failures while maintaining consistency in position, force, moments, and transients. The immediate application of these new devices may be rehabilitation therapy and restoration of movement. Currently in the United States, stroke is the leading cause of disability suffered by over two million stroke survivors and 780,000 new cases annually. The relative incidence of stroke doubles with every decade after age 55, and the leading edge of the "baby boom" has now crossed that border. Consequently there is an urgent need for improved rehabilitation and assistive devices, stemming from inadequate conventional products and a growing population of those in need.

There are several component level actuators that could serve as candidates for synthetic muscles, including those with pneumatic components, electroactive polymer (EAP) components, and shape memory alloy (SMA) components. Each of these candidates has its advantages and disadvantages, and research has to be continued to find component level actuators that can truly match the capability and functionality of biological muscles in terms of allowable max stress, max power density, bandwidth, fatigue life, strain, density, power efficiency and self sensing among others.

Assistance for these current and future victims depends upon three important features of human-machine interactive systems. The first is that human limbs are capable of widely variable ranges of motion in multiple joint configurations. Second, human body types vary with many actuating modalities, ranging from light finger action to strong leg movement. And third, actuation methods must balance high force production and back-drivability for safety and sustained human engagement. These observations call for a new actuation technology with a combination of features that is very difficult to attain with the currently available technology, which makes both inspiration and guidance for such technology in human physiology compelling. These are mostly control issues.

Ultimately, this grand challenge research will initiate both the complete alteration of the actuator design process by providing engineers and researchers a platform to freely update their actuation requirements and a transformative technology that meets the diverse and unpredictable needs of future human-machine interfaces.