2 Concepts of Adaptronic Structures
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2.1 What are Adaptronic Structures?

Adaptronic structures (also referred to as smart materials or intelligent structures) are defined in the literature in the context of many different paradigms; however, two are prevalent. In the technology paradigm, adaptronic structures are seen as an ‘integration of actuators, sensors, and controls with a material or structural component’, see Fig. 2.1. In the science paradigm, adaptronic structures are ‘material systems that have intelligence and life-like features integrated in the microstructure of the material in order to reduce to total mass and energy and produce an adaptive functionality’. The vision and guiding analogy of adaptronic structures is that of learning from nature and living systems in such a way as to enable man-made artifacts to have the adaptive features of autopoiesis we see throughout nature. This leads to the description of the anatomy of an adaptronic material system: actuators or motors that behave like muscles; sensors that have the functionality of the five senses (hearing, sight, smell, taste, and touch); and communication and computational networks that represent the nerves, brain, memory, and muscular control systems [1]. Although the leading analogy is that towards biological systems, it must be emphasized that adaptronic structures are designed by human beings in order to achieve human-related objective. Therefore, the system boundary of the adaptronic structures must necessarily be drawn to include the human end user.

What kind of life-like functions can we expect from adaptronic structures? Natures systems have a few general attributes that we can aspire to instill in synthetic material systems. Many of natures systems can change their properties, shape, color, and load paths to account for damage and allow for repair; and can also manage the graceful retirement of aged systems, to name a few. Engineers and scientists have developed a plethora of devices that are inspired by some of nature’s capabilities; however, little has been accomplished towards realizing the integration of life-like functions at the system level to create materials systems that would be able to learn, grow, survive, and age with grace and simplicity. The survival of biological structures depends on nature’s ability to balance the metabolic cost (economy of construction and maintenance) with the required mechanical properties,
such as strength, toughness, resistance to impact, etc. This balance is precisely what we aim for when we specify material and structural requirements in order to attain a design that simultaneously satisfies economic viability and mission-oriented performance. Besides, a particularly attractive feature of biological systems is their unique ability to diagnose localized damage (through a continuously distributed sensor network) and to initiate a self-repair process. Such an attribute would be a most desirable function in an adaptronic structural system.

Although present day researchers are concentrating on adaptronic structures that may seem rudimentary when compared with mammalian systems, their efforts lay the foundation for the future engineered systems. Controlling the movement of an arm is a wonderful example of the seemingly effortless task that biological creatures perform each day, but which has been quite difficult for engineers to mimic. Consider a situation in which you are sitting at a table that has one leg shorter than the others, and you wish to draw