From Smart Materials to Smart Systems

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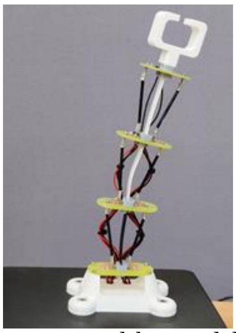
In many fields of engineering, ranging from industry to bio-inspired systems, the need for electro-mechanical devices showing features such as lightweight, compactness, energy efficiency, and accurate controllability of position/force has generated an interest into smart material transducers. These include, e.g., piezoelectric ceramics, shape memory alloys, and electro-active polymers, which have the ability to react to an external stimulus (e.g., electrical, magnetic, thermal) with a modification of their mechanical characteristics (e.g., geometry, force, stiffness). By properly exploiting these features, smart materials allow to develop a new generation of multi-functional and intrinsically intelligent mechatronic devices, which can complement or even improve the performance of conventional actuators in a number of fields. It is remarked, however, that up to date the high potential of smart materials still remains largely unexploited. Aside for issues related to the intrinsic material properties (e.g., low resistance to fatigue, sensitivity to environmental conditions), their strongly nonlinear, hysteretic, and rate-dependent response makes design, modeling, and control of smart material-based systems a highly challenging task. The key to truly embody *smartness* into smart material systems is represented by model-based control and self-sensing algorithms, which are capable to compensate undesired effects and effectively exploit the intrinsic multi-actuator/sensor nature of the transducer. Once available, control and self-sensing methods will enable a whole new generation of smart actuators which are optimized in terms of dynamics performance and energy consumption, do not require external sensors to estimate their configuration and/or force, and provide real-time information on their aging process in an Industry 4.0 environment.



This presentation aims at providing an overview of smart materials in mechatronic applications, by focusing on two recent classes of transducers, i.e., Dielectric Elastomers (DEs) and thermal Shape Memory Alloys (SMAs). Both materials can be used to generate actuation stroke or force by means of a controllable stimulus (voltage and temperature, respectively). An overview of the main characteristics and challenges raised by each material will first be illustrated. Issues related to material system design, modeling, and control will be addressed, and novel applications in mechatronics and robotics will be presented.