Guest Editorial
Introduction to the Special Issue on Dynamics and Control of Smart Structures

SMART structures are an emerging area of research with numerous potential applications in a number of industries. Materials that are used in the construction of smart structures include, but are not limited to, piezoelectric materials, shape memory alloys, magnetorheological and electrorheological fluids and magnetostrictive materials. Most of these materials have been known for a long time. For example, piezoelectricity was first discovered in the early 1800s. The reason for an explosion of recent interest in this area can be attributed to the availability of powerful computers over the past two decades, which has allowed researchers and engineers to control the behavior of smart structural systems in efficient ways. A key factor in guaranteeing high-performance operation of smart structures is the control algorithm. This is the main theme of this special issue.

In preparing this special issue, we adopted two main goals. The first was to introduce this interesting and important area of research to the control community. The second goal was to collect a number of papers that would give an impression of the state of the art in smart structures research.

Smart structures is a truly multidisciplinary field. This can be observed by looking at the affiliation of the contributors to this special issue. The authors have disciplines including electrical engineering, mechanical engineering, aerospace engineering, mathematics and civil engineering. It is our belief that as control engineers, we have a lot to contribute to the shaping of this emerging and important area of research.

Overall, 22 submissions were received for this special issue. All of the manuscripts were rigorously reviewed according to the TRANSACTION's guidelines. The final special issue consists of five papers and seven brief papers, which cover interesting topics related to dynamics and control of smart structures. All papers include experimental results. A brief overview of the special issue follows.

A number of materials that are used in the form of actuators and sensors in construction of smart structures show nonlinear hysteretic behavior. In particular, shape memory alloys and magnetostrictive actuators are known to display wide hysteresis loops. Such nonlinearity can result in instabilities in closed loop operation. It can also, severely, complicate the task of controller design and analysis. Three papers in this special issue deal with the problem of hysteretic actuators.

Gorbet et al. study the energy properties of the Preisach hysteresis model. The Preisach model of hysteresis has attracted considerable interest in recent years and is regarded as a very general description of hysteresis phenomenon. The authors derive passivity properties of the Preisach model directed at the problem of controller design. They demonstrate their work on an SMA rotary actuator. *Cruz-Hernández et al.* propose a method for the design of compensators with a view to reducing hysteresis in transducers. They also introduce two measures for quantifying and comparing the relative performance of controllers. Their method is based on using a unitary gain operator that shifts a periodic signal by a single phase angle, a "phaser," to handle minor hysteresis loops. The authors report experimental results using their controllers on an SMA actuator. *Majima et al.*propose a controller design methodology for SMA actuators that is centered around implementing PID controllers in both feedback and feedforward loops. Further, they introduce a method for identifying parameters of the hysteresis model. Their paper includes experimental results that demonstrate the tracking properties of their controller.

Recently, there has been considerable interest in using electrorheological (ER) and magnetorheological (MR) fluids in various devices. These materials are made from micron-sized particles floating in an oil-like substance. Upon introduction of an electric field, the micron-sized particles in an ER fluid become polarized. This, in turn, changes the viscosity of the fluid. A similar phenomenon occurs in MR fluids upon introduction of a magnetic field. There are two papers in this special issue that address the dynamics and control of smart structures constructed from ER and MR fluids.

Gavin designs a control system using ER fluids for vibration suppression of earthquake-excited structures. The author synthesizes a bang-bang control law using Lyapunov method, which is implemented, using electronic circuitry, on a small scale building model driven by ground accelerations. *Harland et al.* proposes a method for vibration suppression in beam-like structures based on controlling the tunable fluid inserted into the structure. They explain how the applied electric or magnetic field can be adjusted so that the rheological properties of the insert are controlled. They demonstrate their methodology on an experimental apparatus.

Piezoelectric materials are being widely used in a variety of devices and systems. Their ability to transform mechanical energy into electrical energy and *vice versa* makes them ideal actuators and sensors for a number of applications. There are three papers in this special issue that are concerned with piezoelectric actuators and sensors.

Halim et al. propose a method for vibration suppression in flexible structures using colocated piezoelectric actuator/sensor pairs. They introduce a class of decentralized controllers, which guarantee closed-loop stability in the presence of uncontrolled

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vibratory modes. Furthermore, they choose controller parameters, by solving an optimization problem such that vibration of the entire structure is minimized. The authors demonstrate their control design methodology on a piezoelectric laminate beam. *Sana et al.* study the problem of robust control of a PZT driven system with constrained control signals. Piezoelectric actuators can withstand voltages of up to several hundred volts. However, power amplifiers that are needed to derive such highly capacitive loads are often large, complex and expensive. This paper explains how a controller can be designed such that the controller voltage applied to the PZT actuator does not exceed a predefined level. Moreover, they model high-frequency modes as additive uncertainty and design the controller to guarantee closedloop stability of the uncertain system. To ensure sufficient damping, they adopt a pole placement design using linear matrix inequality methods. *Chang et al.* describe a two degree of freedom monolithic piezoelectric actuator that can be used as a nanoactuator with a linear resolution of 2 nanometers and an angular resolution of 1 arc-second. They model this actuator, experimentally validate their model and propose two control algorithms to regulate the motion of their nanopositioner. High-precision commercial micropositioners are extremely expensive devices. It is interesting to see that one may be able to achieve the necessary precision by using the structure proposed by the authors, followed by an appropriate controller design procedure.

This special issue includes four extra papers that are closely related to the area of smart structures. *Cabell et al.* is concerned with in-flight evaluation of the PC-LMS algorithm for feedforward active noise control. Their experiments are done in a Raytheon-Beach 1900D twin-turboprop aircraft. The sensors used are 32 microphones in the passenger compartment of the aircraft. They also use 21 inertial control actuators bolted to the airframe of the plane. *Rhim et al.* compare two time-domain adaptive command shaping approaches in terms of the effect of noise on achievable performance. The paper includes experimental results taken from a gantry robot having a flexible link. The paper by *Kim et al.* is concerned with an active four mount vibration isolation system. Finally *Sane et al.* studies performance of an ARMARKOV adaptive controller on an active noise control system.

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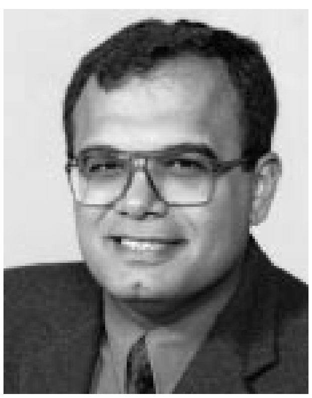

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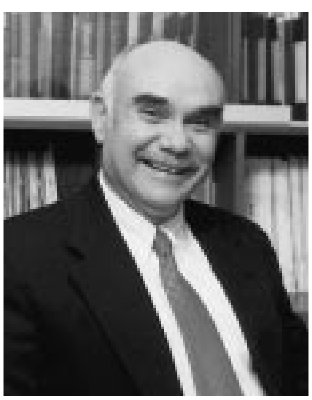

Graham C. Goodwin (F'86) was born in Broken Hill, Australia, in 1945. He received the B.Sc. degree in physics, the B.E. degree in electrical engineering, and the Ph.D. degree from the University of New South Wales, Australia.

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