ABSTRACT

Title of Dissertation: Control of Smart Actuators

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Hysteresis in smart materials hinders wider applicability of such materials in actuators and sensors. In this dissertation we study modeling, identification and control of hysteresis in smart actuators. While the approaches are applicable to control of a wide class of smart actuators, we illustrate the ideas through the example of controlling a magnetostrictive actuator.

Hysteresis exhibited by magnetostrictive actuators is rate-independent when the input frequency is low and we can model it by a Preisach operator. It becomes rate-dependent when the input frequency gets high due to the eddy current effect and the magnetoelastic dynamics. In this case, we propose a new dynamic hysteresis model, consisting of a Preisach operator coupled to an ordinary differential equation in an unusual way. We establish its well-posedness and study its various system-theoretic properties. Existence of periodic solutions under periodic forcing is proved. Algorithms for simulation of the model are also studied. Parameter identification methods for both the Preisach operator and the dynamic model are investigated.

We pursue the problem of hysteresis control along three different but connected paths: inverse control, robust control and optimal control.

The idea of inverse control is to construct an inverse operator to cancel out the hysteretic nonlinearity. Efficient inversion schemes are proposed for both the Preisach model and the dynamic hysteresis model. We also formulate and study a novel inversion problem, called the value inversion problem, and apply it to micro-positioning control.

Inverse compensation is open-loop in nature and therefore susceptible to model uncertainties and to errors introduced in the inverse schemes. We propose a robust control framework for smart actuators by combining inverse compensation with robust control techniques. We present systematic controller design methods which guarantee robust stability and robust trajectory tracking while taking actuator saturation into account.

Finally we study optimal control of hysteresis in smart actuators based on a low dimensional hysteresis model. We characterize the value function as the (unique) viscosity solution to a Hamilton-Jacobi-Bellman equation of a hybrid form, and provide a numerical scheme to approximate the solution.