

Preface

This book explores the control of systems on small length scales. Research and development for micro- and nanoscale science and technology has grown quickly over the last decade, particularly in the areas of microelectromechanical systems (MEMS), microfluidics, nanoelectronics, bio-nanotechnologies, nanofabrication, and nanomaterials. However, to date, control theory has played only a small role in the advancement of this research. As we know from the technical progression of macroscale intelligent systems, such as assembly robots and fly-by-wire aircraft, control systems can maximize system performance and, in many cases, enable capabilities that would otherwise not be possible. We expect that control systems will play a similar enabling role in the development of the next generation of micro- and nanoscale devices, as well as in the precision instrumentation that will be used to fabricate and measure these devices. In support of this, each chapter of this book provides an introduction to an application of micro- and nanotechnologies in which control systems have already been shown to be critical to its success. Through these examples, we aim to provide insight into the unique challenges in controlling systems at small length scales and to highlight the benefits in merging control systems and micro- and nanotechnologies.

We conceived of this book because we saw a strong need to bring the control systems and micro- and nanosystems communities closer together. In our view, the intersection between these two groups is still very small, impeding the advancement of active, precise, and robust micro- and nanoscale systems that can meet the demanding requirements for commercial, military, medical, and consumer products. As an example, we attend conferences for both the control systems and micro- and nanoscale science and technology communities and have found the overlap between attendees to be marginal; maybe in the tens of people. Our hope is that this book will be a step toward rectifying this situation by bridging the gap between these two communities and demonstrating that concrete benefits for both fields can be achieved through collaborative research. We also hope to motivate the next generation of young engineers and scientists to pursue a career at this intersection, which offers all of the excitement, frustration, and eventual big rewards that an aspiring researcher could want.

This book is targeted toward both control systems researchers interested in pursuing new application in the micro- and nanoscales domains, and researchers developing micro- and nanosystems who are interested in learning how control systems can benefit their work. For the former, we hope these chapters will show the serious effort required to demonstrate control in a new application area. All of the contributing authors have acquired expertise in at least one new scientific area in addition to control theory (e.g., atomic force microscopy, optics, microfluidics) in order to pursue their area of research. Acquiring dual expertise can take years of effort, but the payoff can be high by providing results that no expert in a single domain can accomplish. Additionally, it can result in fascinating work (we hope some of the challenges and excitement are conveyed). For researchers in micro- and nanoscale science and technology, this book contains concrete examples of the benefits that control can provide. These range from better control of particle size distribution during synthesis, to high-bandwidth and reliable nanoscale positioning and imaging of objects, to optimal control of the spin dynamics of quantum systems. We also hope this book will be of use to those who are not yet experts in either control systems or micro- and nanoscale systems but are interested in both. We believe it will provide a useful and instructive introduction to the breadth of research being performed at the intersection of these two fields.

The topics covered in this book were selected to represent the entire length scale of miniaturized systems, ranging from hundreds of micrometers down to a fraction of a nanometer (hence our title, *Feedback Control of MEMS to Atoms*). They were also selected to cover a broad range of physical systems that will likely provide new material to most readers.

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Gaithersburg
College Park

Jason J. Gorman
Benjamin Shapiro



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Gorman, J.J.; Shapiro, B. (Eds.)

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