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Guest Editorial

Special Issue on Dynamic Modeling, Control and Manipulation at the Nanoscale

Most of today's emerging nanotechnological applications such as nanoelectromechanical systems require comprehensive modeling, control and manipulation of objects, components and subsystems ranging in sizes from few nanometers to micrometers. An important task amongst many challenging aspects of "nanoscale" manipulation and control design is to overcome the added complexity of uncertainties and nonlinearities that are unique to nanoscale. This added complexity combined with the sub-nanometer precision requirement calls for development of fundamentally new techniques and controllers for these applications. In an effort to respond to such demanding needs for new directions in modeling and control at the nanoscale, this special issue attempts to bring together the current advances in this area and target current research and development efforts in nanoscale control and manipulation techniques including scanning probe microscopy (SPM) systems as well as nanorobotic manipulation.

This Special Issue, consisting of eight papers, presents recent research in the general area of modeling, control and manipulation at the nanoscale. Papers forming this issue can be classified into the following two categories: (I) Scanning Probe Microscopy Systems, and (II) Atomic Force Microscopy Systems. A brief overview of these papers is provided next.

(I) Modeling and Control of Scanning Probe Microscopy (SPM) Systems

The paper authored by Clayton et al. provides a comprehensive review of feedforward control approaches in nanoscale precision positioning for high-speed SPM operation. This article reviews developments in feedforward control for SPMs, which are key enabling tools in nanotechnologies. Feedforward control enables high-speed precision positioning at the nanoscale, which is needed for developing high-speed SPM that can be used to investigate and manipulate dynamic nanoscale phenomena. The paper authored by Landolsi et al. in this category reports on one of the early studies on nanoscale friction dynamic modeling. The success of models in predicting experimental results depends highly on the modeling of friction. This is particularly true at the atomic scale where the nanoscale friction depends on a large set of parameters. This paper presents a novel nanoscale friction model based on the bristle interpretation of single asperity contact. This interpretation is adopted based on dynamic friction models representing stick-slip motion in macrotribology. Another paper in this subject line and authored by Aridogan et al. presents the design and analysis of discrete-time repetitive control for SPMs. In this paper, repetitive control (RC) with linear phase lead compensation is investigated to precisely track periodic trajectories in piezo-based SPMs.

Commercial SPMs use traditional PID feedback controllers; however, the tracking error from such controllers repeat from one operating cycle to the next, and they can be excessively large, especially at high scan rates. A discrete-time repetitive controller is designed, analyzed, and implemented on an experimental SPM to account for the repetitive tracking error.

(II) Modeling and Control of Atomic Force Microscopy (AFM) Systems

Modeling and control issues of AFM systems have recently received increased attention due to the possibility of advanced imaging as well as automated manipulations using AFMs. Along this line, this category collects the papers targeting either modeling, control or manipulation problems in or using AFM systems.

The paper authored by Fantner et al. presents an in depth characterization and control of AFM cantilevers with integrated sensing and actuation. In this paper, the intrinsic properties of a new MEMS cantilever are investigated along with its potential to expand the use of AFM to a broad range of everyday applications in industrial process control and clinical diagnostics. Moving from advances in characterization and control of AFM systems, the paper authored Krohs et al. discusses a probabilistic approach to drift compensation toward autonomous manomanipulation using AFM. This article focuses on thermal drift, which is a crucial error source for automating AFM-based nanoassembly, since it implies a varying, spatial displacement between AFM probe and sample. A novel, versatile drift estimation method based on Monte Carlo Localization (MCL) is presented and validated through experimental results on different AFM systems. The paper authored by Allen et al. presents experimental and analytical evaluation of the effect of tip mass on AFM calibration. Quantitative studies of material properties and interfaces using the AFM have important applications in engineering, biotechnology and chemistry. This work explores the effect of the mass of the probe tip on AFM calibration.

A very recent alteration to conventional AFM systems, the piezoresponse force microscopy (PFM), is introduced in the paper authored by Salehi-Khojin et al. that presents modeling of PFM for low dimensional materials characterization. PFM is an AFM-based approach utilized for measuring local properties of piezoelectric materials. The objective of this study is to propose a practical framework for simultaneous estimation of the local stiffness and piezoelectric properties of materials, such as measurement of local spring constant and piezoelectric coefficient of a Periodically Poled Lithium Niobate (PPLN) microcantilever sample considered in this paper. This method can be particularly applied for accurate characterization of mechanical and piezoelectric properties of biological species and cells. The paper authored by Zou and Wu presents an iterative-based feedforward-feedback control approach to high-speed AFM imaging. AFM imaging requires precision positioning of the AFM probe relative to the sample in all *x*-*y*-*z* axes. In this article, the recently developed current-cycle-feedback iterative-learning-control (CCF-ILC) approach is extended to the entire imaging of samples. The proposed CCF-ILC control approach is illustrated by implementing it to the *z*-axis direction control in AFM imaging. Experimental results show that the imaging speed can be significantly increased by using the proposed approach. As guest editors for this special issue, we would like to thank the contributing authors for submitting their work, the respected reviewers for providing timely evaluation ofpapers, and both past Editor Professor Suhada Jayasuriya and current Editor Professor Karl Hedrick for their vision and support making this special issue a success.

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