Asian Journal of Control, Vol. 20, No. 4, pp. 1315–1316, July 2018
Published online in Wiley Online Library (wileyonlinelibrary.com) DOI: 10.1002/asjc.1912

SPECIAL ISSUE ON RECENT EMERGING TECHNOLOGIES IN ATOMIC FORCE MICROSCOPY

The invention of the atomic force microscope (AFM) has led to numerous breakthroughs in a wide range of fields of science by allowing for imaging down to a nanometer scale. The investion of the AFM was preceded by the invention of the scanning tunnelling microscope (STM) in 1981 by the Swiss scientists Gerd Binnig and Heinrich Rohrer. This invention led to Binnig and Rohrer being awarded the Nobel Prize in Physics. Later, in 1986, Binnig, Quate and Gerber invented the AFM.

The fields in which atomic force microscopy has been applied is continuing to grow and includes materials science, biology, and medicine with applications such as industrial inspection and medical testing. In particular, AFM imaging provides a key tool in the area of nanotechnology. In addition, atomic force microscopy also allows for the manipulation of materials on a nanometer scale. Since the AFM can provide high precision imaging of samples in an aqueous medium, they have proved extremely useful in imaging biological specimens in their natural environment. Also, as opposed to the SPM, the AFM allows for the imaging of samples which are non-conductive. This has enabled the AFM to be applied in areas such as nanolithiography, DNA nanotechnology, optics, microelectronics, material science, and nanofabrication.

The AFM operates by scanning a sample with a physical probe which consists of a sharp tip attached to a flexible cantilever. This scanning in an AFM is typically achieved via the use of a piezoelectric tube actuator. This actuator moves either the sample or the cantilever and probe tip in order to scan the sample and produce an image.

A key feature in the operation of atomic force microscopes is the use of feedback control systems. These control systems are used in the x and y directions in order to accurately scan the sample and in the z direction in order to determine the height of the sample at a given (x, y) position. This enables the AFM to produce a high precision three dimensional image of the sample. However, in most commercially available atomic force microscopes, simple classical control schemes such as PID control are used which means that these AFMs are usually very slow in obtaining accurate images. This has motivated a significant amount of research in the control of AFMs in order to improve their performance.

This special issue includes seven papers which cover recently emerging technologies in atomic force microscopy and in related areas of nanotechnology. The first paper by Rana, Pota and Petersen is a survey paper which surveys different control methods which can be applied to the scanning operation in an AFM. In particular, the paper focuses on control in the x and y directions using a piezoelectric tube scanner. The paper looks at the different challenges to control system design for these problems. The second paper by Habibullah, Pota, and Petersen considers the application of an advance robust control method, namely minimax LQG control, to the control of the x, y position of an AFM scanner in order to achieve a spiral scanning pattern. The controller is designed to achieve robustness against large variations in the sample mass. The third paper by Teo, Yong, and Fleming considers the use of different possible scanning patterns in an AFM and the implications of the choice of scanning patterns on the required bandwidth in the z axis controller. The scanning patterns considered in the paper are the sinusoidal raster, spiral, and Lissajous patterns. The fourth paper by Wu, Lo, Liu, Liu, Chang, and Fu proposes a novel scheme for adaptive tilting angle of the probe within an AFM. The proposed scheme is applied to a dual probe AFM to obtain improved resolution with a reduced number of scans. The fifth paper by Nguyen, Khan, Hatano, Zhang, Edwards, Herrmann, Harniman, Burgess, Antognozzi, and Miles shows the design of a sliding mode observer to estimate the cantilever shear force in a transverse dynamic force microscope. This method uses a simplified model of the AFM which is obtained from a PDE model. The method also applies an unknown input sliding mode observer. The sixth paper by Schimmack and Mercorelli describes the use of a wavelet packet tree denoising method when applied to AFM images. This enables the AFM to achieve better images without the need for hardware changes. The seventh and last paper by Jamshidifar, Askari and Fidan moves away from the consideration of AFMs and considers a related nano-positioning problem involving the control of carbon nanotube resonators. This paper involves both modelling and parameter identification of the resonator system. It also involves the use of adaptive control.

We hope that the readers of the journal will benefit from reading this collection of papers, and be motivated to undertake their own research in this exciting area. Finally, the guest editors wish to thank Professor Li-Chen Fu, Editor-in-Chief of Asian Journal of Control for suggesting that we put together this special issue, and all the authors and the reviewers for their contributions.

Guest Editors
Ian R. Petersen
Australian National University
E-mail: i.r.petersen@gmail.com

S. O. Reza Moheimani
University of Texas at Dallas

Ian R. Petersen was born in Victoria, Australia. He received a Ph.D in Electrical Engineering in 1984 from the University of Rochester. From 1983 to 1985 he was a Postdoctoral Fellow at the Australian National University. From 1985 until 2016 he was with UNSW Canberra where was a Scientia Professor and an Australian Research Council Laureate Fellow. He has previously been ARC Executive Director for Mathematics Information and Communications, Acting Deputy Vice-Chancellor Research for UNSW and an Australian Federation Fellow. From 2017 he has been a Professor in the Research School of Engineering at the Australian National University. He is currently Director of the Research School of Engineering at the ANU. He has served as an Associate Editor for the IEEE Transactions on Automatic Control, Systems and Control Letters, Automatica, IEEE Transactions on Control Systems Technology and SIAM Journal on Control and Optimization. Currently he is an Editor for Automatica. He is a fellow of IFAC, the IEEE and the Australian Academy of Science. His main research interests are in robust control theory, quantum control theory and stochastic control theory.

Reza Moheimani currently holds the James von Ehr Distinguished Chair in Science and Technology in Department of Mechanical Engineering at the University of Texas at Dallas. His current research interests include ultrahigh-precision mechatronic systems, with particular emphasis on dynamics and control at the nanometer scale, including applications of control and estimation in nanopositioning systems for high-speed scanning probe microscopy and nanomanufacturing, modeling and control of microcantilever-based devices, control of microactuators in microelectromechanical systems, and design, modeling and control of micromachined nanopositioners for on-chip scanning probe microscopy. Dr. Moheimani is a Fellow of IEEE, IFAC and the Institute of Physics, U.K. His research has been recognized with a number of awards, including IFAC Nathaniel B. Nichols Medal (2014), IFAC Mechatronic Systems Award (2013), IEEE Control Systems Technology Award (2009), IEEE Transactions on Control Systems Technology Outstanding Paper Award (2007) and several best student paper awards in various conferences. He is the Editor-in-Chief of Mechatronics and has served on the editorial boards of a number of other journals, including IEEE TRANSACTIONS ON MECHATRONICS, IEEE TRANSACTIONS ON CONTROL SYSTEMS TECHNOLOGY, and Control Engineering Practice. He has been chair of the IFAC Technical Committee on Mechatronic Systems.