Western Australia Section

Joint Chapter ESP:
Electron Devices Society
Solid State Circuits Society
Photonics Society

Self-Sensing, Estimation and Control in Multifrequency Atomic Force Microscopy

A Seminar of the IEEE WA joint EDS/SSCS/IPS Chapter

Michael G. Ruppert
School of Electrical Engineering and Computing
The University of Newcastle, Callaghan, NSW

Friday, 19 May 2017 @ 2.00 PM

Venue: **Billings Room 3.04, 3rd floor. Electrical & Electronic Engineering Building**
University of Western Australia, Crawley

This seminar is open to the public and admission is free to all IEEE members and non-members

Abstract:

Despite the undeniable success of the Atomic Force Microscope (AFM), dynamic techniques still face limitations in terms of spatial resolution, imaging speed and high cost of acquisition. In order to expand the capabilities of the instrument, it was realized that the information about the nanomechanical properties of a sample are encoded over a range of frequencies and the excitation and detection of higher order eigenmodes of the microcantilever open up further information channels. The ability to control these modes and their fast responses to excitation is believed to be the key to unravelling the true potential of these methods. This work highlights a number of drawbacks of a standard AFM setup, which limit the realizability of multifrequency approaches. First, a class of probes based on microelectromechanical system (MEMS) design is motivated, which enable the development of self-sensing/self-actuating techniques. Specifically, these piezoelectric transduction schemes enable the miniaturization of the AFM towards a cost-effective single-chip device with nanoscale precision in a much smaller form factor than that of conventional macroscale instruments. Second, the integrated actuation enables multimode controllers which exhibits remarkable performance in arbitrarily modifying the quality factor of multiple eigenmodes and comes with inherent stability robustness.
The experimental results demonstrate improved imaging stability, higher scan speeds and adjustable contrast when mapping nanomechanical properties of soft samples. Lastly, in light of the demand for constantly increasing imaging speeds while providing multifrequency flexibility, the estimation of multiple components of the high-frequency detection signal is performed with a linear time-varying multifrequency Kalman filter. The chosen representation allows for an efficient high-bandwidth implementation on a Field Programmable Gate Array (FPGA). Tracking bandwidth and noise performance are shown to be superior to that of the commonly used lock-in amplifier.

Biography:

Michael Ruppert received the Dipl.-Ing. degree in automation technology in production, with a specialization in systems theory and automatic control, from the University of Stuttgart, Germany, in 2013. In 2017, he received the Ph.D. degree in electrical engineering from The University of Newcastle, Australia where he is now a Postdoctoral Research Associate with the School of Electrical Engineering and Computing. As a Visiting Researcher, he was with the Mechanical Engineering Department, University of Texas at Dallas, USA. His research interests include the control, estimation and self-sensing of microelectromechanical (MEMS) systems such as piezoelectric microcantilever and nanopositioning systems for multi-frequency and single-chip atomic force microscopy.
Dr. Ruppert received the Academic Merit Scholarship from the University of Stuttgart, the Baden- Württemberg Scholarship, and held Postgraduate Research Scholarships with the University of Newcastle and with the CSIRO, Clayton, VIC, Australia. Dr. Ruppert's research has been recognized with the 2013 IEEE/ASME International Conference on Advanced Intelligent Mechatronics (AIM) Best Conference Paper Finalist Award and with The University of Newcastle FEBE Postgraduate Research Prize in 2014 and 2016.