2nd Workshop on Dynamics and Control of Micro and Nanoscale Systems

The University of Newcastle, 23-24 February 2012
# 2nd Workshop on Dynamics and Control of Micro and Nanoscale Systems

**The University of Newcastle, Australia**

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**Program Thursday, February 23, 2012**

Advanced Technology Centre Lecture Room

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Microrobotics has recently entered the phase in which sub-mm sized autonomous robots are being realized. While the potential impact of these devices on society is high, particularly for biomedical applications, many challenges remain in developing genuine microrobots that will be useful to society. This talk will provide an overview of the field and will then focus on applications of microrobots for ophthalmic-retinal therapies. Issues in the design of external systems for providing energy and control of microrobots must be considered, and the use of externally generated magnetic fields in particular appears to be a promising strategy. Theoretical and experimental issues will be discussed. Functionalization of the devices and efforts to scale microrobots to the nanodomain will be presented.

**Biography**

Brad Nelson is the Professor of Robotics and Intelligent Systems at ETH Zürich. His primary research focus is on microrobotics and nanorobotics with an emphasis on applications in biology and medicine. He received a B.S.M.E. from the University of Illinois at Urbana-Champaign and an M.S.M.E. from the University of Minnesota. He has worked as an engineer at Honeywell and Motorola and served as a United States Peace Corps Volunteer in Botswana, Africa, before obtaining a Ph.D. in Robotics from Carnegie Mellon University in 1995. He was an Assistant Professor at the University of Illinois at Chicago (1995-1998) and an Associate Professor at the University of Minnesota (1998-2002). He became a Full Professor at ETH Zürich in 2002 and has recently become an Adjunct Professor at the Daegu Gyeongbuk Institute of Science and Technology (DGIST).

Prof. Nelson has received a number of awards including more than a dozen Best Paper Awards and Award Finalists at major robotics conferences and journals. He was named to the 2005 “Scientific American 50,” Scientific American magazine’s annual list recognizing fifty outstanding acts of leadership in science and technology from the past year for his efforts in nanotube manufacturing. His laboratory won the 2007 and 2009 RoboCup Nanogram Competition, both times the event has been held. His lab appears in the 2012 Guinness Book of World Records for the "Most Advanced Mini Robot for Medical Use." He serves on the editorial boards of several journals.
High-speed Micro-robot in Microfluidic Chip

Professor Fumihito Arai
Nagoya University

Integration of the microfluidics and robotics based on MEMS technology is unique approach for biomedical innovations. In addition to the advantage of environmental control by microfluidic chip, microrobotic technology enables physical operation to the cell with high throughput. Microfluidic systems having high-speed microrobots are designed and applied for biomedical innovations.

Biography

Fumihito Arai received the Master of Eng. degree from the Tokyo Univ. of Science in 1988. He joined Nagoya University, Japan in 1989 as Research Associate. He received Dr. of Eng. from Nagoya University in 1993. Since 1998, he was Associate Professor of Department of Micro System Eng., Nagoya University. Since 2005, he is Professor of Department of Bioengineering and Robotics, Tohoku University. Since 2010, he is Professor of Nagoya University, mainly engaging in the research fields of micro- and nano-robotics and its application to the micro- and nano-assembly and cell manipulation, bio-automation systems, medical robotic systems, Micro and Nano Electro Mechanical Systems, intelligent robotic systems.
In clinical applications such as for cancer therapies, navigational control of drug-loaded microcarriers through the human vascular network offers many advantages compared to actual methods such as chemotherapy. Indeed, by directly targeting tumors using the most direct route, systemic circulation can be avoided and as such, therapeutic efficacy can potentially be enhanced substantially while eliminating or at least minimizing secondary toxicity for the patients. But the environmental conditions in larger vessels such as arteries and narrower vessels such as capillaries put major technological constraints which require complementary methods for navigating and controlling these microcarriers. In this talk, the main constraints will be reviewed and the preferred methods and platforms used to achieve such navigation and the related navigational control will be briefly described. More specifically, the talk will describe appropriate control methods for Magnetic Resonance Navigation (MRN), i.e. navigation based on Magnetic Resonance Imaging (MRI) technology to provide actuation and imaging modality when operating in larger vessels. Furthermore, to go beyond the limitation of MRN, the talk will conclude with the control methods of bacterial actuation-based drug-loaded microcarriers in the tiniest vessels where the spatial resolution of any modern medical imaging modalities is insufficient to gather the real-time tracking data required to achieve closed-loop control.

Biography

Sylvain Martel received the Ph.D. degree in Electrical Engineering from McGill University, Institute of Biomedical Engineering, Montréal, Canada, in 1997. Following postdoctoral studies at the Massachusetts Institute of Technology (MIT), he was appointed Research Scientist at the BioInstrumentation Laboratory, Department of Mechanical Engineering at MIT. From Feb. 2001 to Sept. 2004, he had dual appointments at MIT and as Assistant Professor in the Department of Electrical and Computer Engineering, and the Institute of Biomedical Engineering at École Polytechnique de Montréal (EPM), Campus of the University of Montréal, Montréal, Canada. He is currently Professor in the Department of Computer Engineering and the Institute of Biomedical Engineering, and Director of the NanoRobotics Laboratory at EPM that he founded in 2002. Dr. Martel holds the Canada Research Chair (CRC) in Micro/Nanosystem Development, Fabrication and Validation since 2001. He has over 200 refereed publications, several patents, gives several invited presentations annually, and he is an active member in many international committees and organizations worldwide. Dr. Martel’s main expertise is in the field of nanorobotics, micro- and nano-systems, and the development of novel instrumented platforms and a variety of related support technologies targeted mainly for biomedical and bioengineering applications, and nanotechnology. He has a vast experience in electronics, computer engineering, and also worked extensively in biomedical and mechanical engineering.
In the past, Dr. Martel developed several innovative systems including the first parallel computer specialized for remote micro-surgeries, new medical systems used worldwide for isochronal and isopotential direct cardiac mappings capable to operate under cardiac defibrillations and enabling world leading cardiologists to better understand the causes of sudden cardiac death and ventricular fibrillation. He developed new types of computers and networks, hundreds of other electronic systems including dynamically reconfigurable networked control systems, and developed with internationally renowned neurologists at Brown University, new brain-machine implants and interfaces.

Presently, Dr. Martel leads a multidisciplinary team involved in research and development of new instrumented platforms mainly for the medical field and in bioengineering. He is also involved in the development of nano-factories based on a fleet of scientific instruments configured as autonomous miniature robots capable of high throughput screening in biotechnology and autonomous operations at the molecular scale. He is also active in the development of minimally invasive tools based on microdevices propelled in the blood vessels by magnetic gradients generated by Magnetic Resonance Imaging (MRI) systems for tumor targeting and other applications. He is also active in the development of biosensors designed to be navigated through the blood vessels that could potentially be targeted at the brain for non-invasive recording and imaging of brain activities with high spatial resolution. He is also developing various microsystems using and integrating magnetotactic bacteria as computer controlled functional components for various applications including but not limited to the fast detection of pathogenic bacteria and as bio-carriers for drug delivery in cancer therapy. As such, he is leading highly interdisciplinary projects that include Micro-Electro-Mechanical System (MEMS), System-on-Chip (SoC)-based microsystems, microbiology, nanotechnology, and many other fields.

Beside its academic and industrial experience, between 1976 and 2004, Dr. Martel had several positions in the Canadian Naval Reserve, including 8 years as ship’s diver and supervisor, and many years as navigator, operations officer, etc., and participated in several NATO exercises. From 1994 to 2004, he was acting as warship commanding officer involved mainly in coastal defense operations along the Atlantic and Pacific coasts.
Exploiting parametric Resonance in Electrostatic MEMS

Gary K. Fedder and Congzhong Guo
Carnegie Mellon University

Parametric resonance in electrostatically actuated MEMS gives rise to complex nonlinear phenomena. In particular, bifurcation of resonant states in MEMS has been extensively studied through analytic perturbation analysis. Certain kinds of nonlinearity give rise to flat and large amplitude response over relatively large frequency ranges that are potentially useful in making manufacturable resonant drives, for example for gyroscopes, scanning mirrors, or in sensors that need motion for chopper stabilization. In another operational mode, parametric pumping enhances the system resonant gain and can narrow effective bandwidth. In sensing applications, control at the bifurcation point results in extremely sensitive detection of mass or stress. Implementation of these various kinds of nonlinear systems is still in its infancy. Recent validation of circuit-level behavioral modeling for parametric resonant systems has offered hope for accurate predictive capability in design. The exploration of new parametric resonant topologies and of corresponding control methods is intractable analytically and benefits from accurate system simulation with detailed micromechanical dynamics.

Biography

Gary K. Fedder is a Professor at Carnegie Mellon University holding a joint appointment with the Department of Electrical and Computer Engineering and The Robotics Institute. He received the B.S. and M.S. degrees in EECS from MIT in 1982 and 1984, respectively. From 1984 to 1989, he worked at the Hewlett-Packard Company on a VLSI integrated-circuit test system and on modeling of printed-circuit-board interconnect for high-speed computers. In 1994, he received the Ph.D. degree in EECS from the University of California at Berkeley, where his research resulted in the first demonstration of multimode control of an underdamped surface-micromachined inertial device. He received the 1993 AIME Electronic Materials Society Ross Tucker Award, the 1996 Carnegie Institute of Technology G. T. Ladd Award, and the 1996 NSF CARRER Award. Currently, he serves as a subject editor for the IEEE/ASME Journal of Microelectromechanical Systems, on the editorial board of the IoP Journal of Micromechanics and Microengineering, and as co-editor of the Wiley-VCH Sensors Update and Advanced Micro- and Nanosystems book series. He served as general co-chair of the 2005 IEEE MEMS Conference. He has contributed to over 100 research publications and several patents in the MEMS area. His research interests include microsensor and microactuator design and modeling, integrated MEMS manufactured in CMOS processes and structured design methodologies for MEMS.
Precise positioning at the nanometer scale is a key enabling technology in nanoscale science and engineering. Recent advances in nanotechnology applications ranging from nanolithography tools and semiconductor device metrology to molecular biology and data storage are fundamentally based on the ability to interrogate and manipulate matter at the nanometer scale. The vast range of applications with such diverse operating conditions poses new challenges for the nanopositioning devices because they necessitate extremely high precision and high bandwidth control of motion. Our research focuses on the development of an integrated framework for high-speed nanopositioning. Specifically, the research challenges are tackled from three different perspectives, namely, by developing advanced control algorithms, applicable also to conventional nanopositioning stages; by developing and designing novel actuation and sensing schemes; and finally, by developing new spatial trajectories for high-speed scanning. In this talk, a description and experimental results of each of the approaches will be presented.

**Biography**

Angeliki Pantazi received the Diploma and Ph.D. degrees in Electrical Engineering and Computers Technology from the University of Patras, Greece, in 1996 and 2005, respectively. She currently is a Research Staff Member at IBM Research – Zurich, in Rüschlikon, Switzerland. Her research interests include scanning-probe techniques with emphasis on high-speed nanopositioning, enabling technologies for phase-change memory, and magnetic tape drive systems. Dr. Pantazi is a co-recipient of the 2009 IEEE CCS Control Systems Technology Award and the 2009 IEEE Transactions on Control Systems Technology Outstanding Paper Award.
Reconstruction of Real Topographic Images Distorted by Nonlinearities of a Vertical Scanner in Atomic Force Microscopy
Cheolsu Han$^1$ and Chung Choo Chung$^2$
$^1$Department of Electrical and Computer Engineering, Hanyang University, Republic of Korea
$^2$Department of Electrical and Biomedical Engineering, Hanyang University, Republic of Korea

The atomic force microscope (AFM) is a powerful tool for measuring and manipulating materials with various characteristics in nanometer science and technology. Reconstruction of scanned topographic images is a very important research topic in AFM metrology. In this talk, we introduce a systematic reconstruction method of topographic images distorted by nonlinearities of a Z-scanner. We analyze the illusory slopes of scanned topographic image caused by the nonlinearities such as creep and hysteresis of the Z scanner operated in constant-force mode. The illusory slope appearing in the slow scanning is highly related to the creep effect of the Z-scanner. In the controller for a Z-scanner, a position-sensitive detector is utilized to maintain a user-defined set-point or force between tip and sample surface. This serves to eliminate undesirable effects. In the conventional constant-force mode, the amplitude of the control signal is used to construct a scanned image. However, the control signal contains not only the topography data of the sample, but also undesirable effects. Consequently, the scanned image includes the illusory slope due to the creep effect of the Z-scanner. For a fast automatic scanning process, which requires fast scanning and high reproducibility, sample scanning is needed immediately right after the approach operation has been completed. In the case, the scanned image may be badly distorted by rapid changes in the early stage of the creep effect. We present a new method to obtain the tilt angle of a sample and the creep factor of the Z-scanner. This method does not require user experience. The image distortion can be measured and systematically removed. The proposed method also reduces the artifacts caused by flattening without consideration of flattening process or the numerical creep model of Z-scanner. We test the proposed method using a calibration sample and evaluate the flattened image using a histogram graph.

Biography

Chung Choo Chung was born in Incheon, Korea, on September 5, 1958. He received the B.S. and M.S. degrees from Seoul National University, Seoul, Korea, in 1981 and 1983, respectively, and the Ph.D. degree from the University of Southern California, Los Angeles, in 1993, all in electrical engineering.

From 1983 to 1985, he was a Research Engineer at the Central Research Laboratory, GoldStar (currently LG Electronics), Seoul, where he was engaged in the areas of robotics and copiers. In 1985, he joined the International Procurement Office (IPO), IBM Korea, where he was a Procurement and Quality Assurance Associate Engineer until 1987. From 1993 to 1994, he was a Research Associate in electrical and computer engineering at the University of Colorado at Boulder. From 1994 to 1997, he was with Samsung Advanced

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Institute of Technology (SAIT), Korea, where he was a Team Leader and developed a disk drive servo development system. He finished the Samsung Advanced Management Program at the Wharton Business School, University of Pennsylvania, Philadelphia. In 1997, he joined the faculty of Hanyang University, Seoul, where he was the Chairman of the Division of Electrical and Computer Engineering from 2004 to 2005, the Associate Dean for Planning, College of Engineering, from 2006 to 2008, and has been a Professor since 2007. He was an Associate Editor for the Asian Journal of Control from 2000 to 2002, the Director of the Editorial Board for the Transactions on Control, Automation and Systems Engineering from 2001 to 2002, and the Editor for the International Journal of Control, Automation and Systems from 2003 to 2005. His current research interests include the control areas of robotic systems, automotive systems, power systems, lithography systems, and data storage systems, including hard disk drives, optical disk drives, holographic data storage systems, and scanning-probe-microscope-based storage systems.

Prof. Chung is a member of the American Society of Mechanical Engineers (ASME), the Institute of Control, Robotics and Systems (ICROS), and the Korean Institute of Electrical Engineers (KIEE). He is the Program Co-Chair of the International Conference on Control, Automation and Systems (ICCAS) of the Society of Instrument and Control Engineers (SICE) 2009, Fukuoka, Japan. In 1996, he was selected as one of the Samsung 21st Century Leaders by the Samsung Group. He was an Associate Editor for the 2003 IEEE Conference on Decision and Control. He was an Associate Editor and the Co-Chair of Publicity of the International Federation of Automatic Control (IFAC) World Congress, Korea, 2008. He has chaired numerous sessions and was a member of a number of International Program Committees of various IEEE, ASME, ICROS, SICE, Asian Control Conference (ASCC), and IFAC conferences. Since 2000, he has been the President of the Control Theory Study Society of the ICROS, Korea.
High-performance nanopositioning stages are critical in applications such as atomic force microscope (AFM) imaging, fiber optic alignment, and micro and nanomachining. Particularly, video-rate scanning probe microscopy (SPM) and high-throughput probe-based nanomanufacturing require nanopositioners capable of fast and accurate movements. This talk will focus on recent advances in mechanical design and the development of repetitive controllers for high-speed nanopositioning. Specifically, compliant serial-kinematic systems and dual-stage vertical positioning will be presented. Due to the inherent nonlinearities (hysteresis in piezoactuators) and induced structural vibrations in the positioning stage, the repetitive control (RC) approach will be introduced for tracking periodic reference trajectories and/or to reject periodic disturbances. However, the hysteresis behavior in piezo-based nanopositioners, if significant, can drastically limit the performance of RC designed around a linear dynamics model. To address this issue, the effect of hysteresis on the closed-loop stability of RC will be discussed and when the hysteresis effect is significant, an inverse-hysteresis feedforward controller based on the Prandtl–Ishlinskii hysteresis model will be discussed to handle the nonlinearity. Experimental SPM results will be presented to demonstrate scanning in the kHz frequency range.

Biography

Kam K. Leang received the B.S. and M.S. degrees in mechanical engineering from the University of Utah, Salt Lake City, in 1997 and 1999, respectively, and the Ph.D. degree from the University of Washington, Seattle, in 2004.

He is currently an Assistant Professor in the Mechanical Engineering Department, University of Nevada, Reno, which he joined in 2008. From 2005 to 2008, he was with the Mechanical Engineering Department, Virginia Commonwealth University, Richmond. His current research interests include modeling and control of piezoactuators for scanning probe microscopy applications, fabrication and control of electroactive polymers, and design of MEMS for nanotechnology.

Dr. Leang is a member of the American Society of Mechanical Engineers (ASME) and the International Society for Optical Engineers (SPIE).
Mechatronic imaging systems, such as atomic force microscopes (AFM), wafer scanners, adaptive optics, and scanning laser microscopy, demand a continuous improvement of scanning- and positioning systems in terms of speed and actuation range while maintaining highest spatial resolution on the nanometer scale. This contribution discusses various developments to address these challenges and presents examples for AFM imaging.

Dual actuation enables a significant improvement of the positioning bandwidth while maintaining a large actuation range. For the short-stroke actuator, potential limitations of the feedback bandwidth can be avoided in the mechatronic design. The design of a model-based controller directly addresses the trade-off between the cross-over frequency and the potential fighting between both actuator loops.

Fast operation of scanning systems by means of iterative learning control allows for precise and high-speed scanning beyond the achievable bandwidth of feedback control and beyond the noise floor of the position sensor. Self-sensing actuation enables soft sensing and active damping of piezo-based nano-positioners without the need for explicit position sensors.

The examples presented demonstrate improvement of system performance and reduction of instrumentation costs, utilizing the interplay between process design and control design by mechatronic system integration.

**Biography**

Georg Schitter is Professor for Industrial Automation at the Automation and Control Institute (ACIN) in the School of Electrical Engineering and Information Technology of the Vienna University of Technology.

His primary research interests are on high-performance mechatronic systems and multidisciplinary systems integration, particularly for precision engineering applications in the high-tech industry, scientific instrumentation, and mechatronic imaging systems that require precise positioning combined with high bandwidths, such as scanning probe microscopy, adaptive optics, and lithography systems for semiconductor industry.

Prof. Schitter received a M.Sc. (Electrical Engineering) from the Graz University of Technology, Austria, in 2000 and a M.Sc. (Information Technology) and a Ph.D. (Nanotechnology) from the Swiss Federal Institute of Technology (ETH) Zurich in 2004. From 2004-2006 he worked as a postdoctoral fellow in the laboratory of Prof. Paul Hansma at the University of California Santa Barbara (UCSB). In 2006 he became Assistant Professor
at Delft University of Technology, the Netherlands, was promoted to Associate Professor in 2009, and became Professor at Vienna University of Technology in 2010.

He was a recipient of several prestigious fellowships and awards, among them the best paper award from the Asian Journal of Control (2004-2005) and from the IFAC Journal Mechatronics (2008-2011). He is a member of IEEE, IFAC, ASME, and APS. Georg Schitter serves as an Associate Editor for the IFAC Journal Control Engineering Practice, for the IFAC Journal Mechatronics, for the IEEE/ASME Transactions on Mechatronics, and at the Conference Editorial Board of the IEEE Control Systems Society (CSS).
Video Rate Imaging using Atomic Force Microscopy

Ning Xi
Department of Electrical and Computer Engineering
Michigan State University

Atomic Force Microscopy (AFM) is a useful tool in nano scale imaging in both air and liquid. However, an AFM usually takes several minutes to get an image due to the limitation of the scan rate. Therefore it is difficult to use an AFM to observe dynamic changes in real-time. There is an increasing demand on fast imaging AFM system. Hardware improvement might be one of the solutions. But it needs much faster and stable AFM scanner and controller to achieve fast scan. In reality, it is still difficult to obtain high resolution and stable video-rate imaging. In this presentation, a methodology to achieve a video-rate AFM imaging by smart scan will be introduced. Based on the theory of compressive sensing, new scan patterns have been developed. Instead of scanning line by line over the imaging area, a special pattern will be developed based on the characteristics of the image. As a result, it is no longer necessary to scan everywhere in a sample to get an image. The selected scanning will provide sufficient information to recover the entire image. This will significantly reduce the amount of the scanning time and achieve a video-rate AFM imaging. Furthermore, the video-rate AFM images can also provide accurate position information of an AFM probe. It can be used to replace the position sensor that usually introduces measurement noises and to enable high-precision motion control. A new non-vector space motion controller for nano-scale manipulation has been developed using the video-rate AFM images. These new imaging and motion control methods have been successfully applied to many applications such as observing chemical synthesis in real time, nano robotic manipulation, and nano assembly.

Biography

Ning Xi received his D.Sc. degree in Systems Science and Mathematics from Washington University in St. Louis, Missouri in December, 1993. He received his M.S. degree in computer science from Northeastern University, Boston, Massachusetts, and B.S. degree in electrical engineering from Beijing University of Aeronautics and Astronautics. Currently, he is John D. Ryder Professor of Electrical and Computer Engineering in the Department of Electrical and Computer Engineering at Michigan State University. Dr. Xi received the Best Paper Award in IEEE/RSJ International Conference on Intelligent Robots and Systems in August, 1995. He also received the Best Paper Award in the 1998 Japan-USA Symposium on Flexible Automation. Dr. Xi was awarded the first Early Academic Career Award by the IEEE Robotics and Automation Society in May, 1999. In addition, he is also a recipient of National Science Foundation CAREER Award. Currently, his research interests include robotics, manufacturing automation, micro/nano systems, and intelligent control and systems.
Learning to Read: DNA Sequencing Technologies and the $1000 Genome – The DNA Transistor Approach

Stefan Harrer
IBM Research and Development – Australia

The information to produce many of the components of the cell such as RNAs and proteins is encoded in the sequence of nucleotides of a cell. Determining the DNA sequence is therefore fundamental to molecular biology and medicine. The most used technique for DNA sequencing has been the dideoxy termination method developed by F. Sanger in a Nobel Prize winning groundbreaking work. Through parallelization, automation and refinement of the established Sanger sequencing method, the Human Genome Project is estimated to have cost $3 billion. Much lower cost methods for DNA sequencing will be required to make genome sequencing feasible for routine healthcare practice.

Many new generation sequencing methods have been developed during the last decade, which represent significant advances over the traditional Sanger sequencing. Amongst them, a method based on threading a DNA molecule through a pore of a diameter of a few nanometers to sequence this molecule while it translocates through the nanopore occupies a privileged place. DNA nanopore sequencing has the advantage of being a real-time single molecule DNA sequencing method with little to no sample preparation and inherently of low-cost.

At least two technical roadblocks prevent implementations of DNA nanopore nucleotide identification by electrical sensor methods. 1) The absence of a reliable approach to control the translocation of DNA through the nanopore. 2) The technical difficulties in making sufficiently small sensors. Our work in this field focuses on solving the challenge of translocation control.

To control the DNA translocation through the nanopore we have proposed a device consisting of a metal/dielectric/metal/dielectric/metal multilayer nano-structure built into the membrane that contains the nanopore. Voltage biases between the electrically addressable metal layers will modulate the electric field inside the nanopore. This device utilizes the interaction of discrete charges along the backbone of a DNA molecule with the modulated electric field to trap DNA in the nanopore with single-base resolution. By cyclically turning on and off these gate voltages, we showed theoretically, and we expect to be able to prove experimentally, the plausibility to move DNA through the nanopore at a rate of one nucleotide per cycle. We call this device a DNA transistor, as a DNA current is produced in response to modulation of gate voltages in the device.

The DNA transistor is then a DNA positional controlling platform with single-base-resolution, which could be used in combination with sensor measurements that are under development by us and other research groups. By providing enough dwell time for each DNA nucleotide at the electrodes constituting the sensor, the DNA transistor allows exploration of the best electrical sensor that can resolve the difference between the four DNA nucleotides. In that sense, the DNA transistor paves the way to nanopore-based nucleotide sequencing, and personalized medicine.
Biography

Stefan Harrer received the B.Sc., Diploma, and Ph.D. degrees in electrical engineering and computer science with special focus on medical engineering, nanotechnology and nanoelectronics from the Technical University of Munich, Munich, Germany, in 2003, 2004, and 2008, respectively, and a Honors Masters Certificate in technology management from the Technical University of Munich and the Ludwig-Maximilians Universitaet Muenchen, Munich, in 2003. He studied technology management at the Center for Digital Technology and Management, Ludwig-Maximilians Universitaet Muenchen, the Technical University of Munich, and the University of California, Berkeley from 2001-2003. During 2005-2006 he was a Visiting Graduate Student in the Department of Electrical Engineering and Computer Science, Massachusetts Institute of Technology, Cambridge, where he was involved in implementing new nanoimprint lithography and nanotransfer lithography techniques. In 2008 he joined the International Business Machines Corporation as a process development engineer in the Advanced Lithography Group, IBM Research Division, Albany, NY, working on nanofabrication technologies with special focus on nanoimprint lithography, immersion lithography, and direct self-assembly technology. In 2009 he became a research scientist in the Systems Biology and Functional Genomics Group at the IBM T. J. Watson Research Center, Yorktown Heights, NY, where he worked on implementing and developing novel DNA-sequencing technologies as an investigator of the National Human Genome Research Institute (NHGRI) Grant “Nanopore-based Electrical Device for DNA Sequencing”. Since 2011 he is a Senior Research Staff Member in the newly opened IBM Research Laboratory in Melbourne, Australia, where he is responsible for IBM’s Medical Engineering R&D with special focus on Biosensors and Smarter Planet healthcare applications. Since 2012 he is also an Honorary Principal Research Fellow of the Department of Electrical and Electronic Engineering at the University of Melbourne, Australia. He has authored or coauthored numerous technical publications, and has 15 patents pending. Dr. Harrer was awarded the IEEE Best Student Paper Award at the 6th IEEE International Conference on Nanotechnology 2006, Cincinnati, OH, the IBM PreT0 Best Poster Presentation Award 2009 at IBM’s PreT0 Conference 2009, Albany, NY, the IEEE Most Innovative Paper Award 2009 at the Annual IBM Semiconductor Technology Symposium 2009, Yorktown Heights, NY, an IBM Patent Application Invention Achievement Award 2010, an IBM First Plateau Invention Achievement Award 2010, an IBM Second Plateau Invention Achievement Award 2011, and an IBM Third Plateau Invention Achievement Award 2012 respectively. He is a member of several scientific societies, including the IEEE and the New York Academy of Sciences.
Handling Narrow-Band Disturbances in Precision Motion Control Systems

Masayoshi Tomizuka
Cheryl and John Neerhout, Jr. Distinguished Professor
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Many servo systems are subjected to narrowband disturbances that generate vibrations at multiple frequencies. Disturbance frequencies may or may not be known in advance. In this talk, we will review different approaches to handle narrow-band disturbances and discuss recent developments in this area at the Mechanical Systems Control (MSC) Laboratory at the University of California, Berkeley. These algorithms are evaluated on a simulated hard disk drive (HDD) benchmark problem. The work reported in this talk has been performed jointly with Xu Chen, a PhD student at UCB.

Biography

Masayoshi Tomizuka received his B.S. and M.S. degrees in Mechanical Engineering from Keio University, Tokyo, Japan and his Ph. D. degree in Mechanical Engineering from the Massachusetts Institute of Technology in February 1974. In 1974, he joined the faculty of the Department of Mechanical Engineering at the University of California at Berkeley, where he currently holds the Cheryl and John Neerhout, Jr., Distinguished Professorship Chair and serves as Associate Dean of Engineering. He teaches courses in dynamic systems and controls. His current research interests are optimal and adaptive control, digital control, signal processing, motion control, and control problems related to robotics and rehabilitation, vehicles and mechatronic systems. He served as Program Director of the Dynamic Systems and Control Program of the National Science Foundation (2002-2004). He has supervised more than 95 PhD students to completion. He has published over 550 articles in professional journals and conference proceedings.

He served as Technical Editor of the ASME Journal of Dynamic Systems, Measurement and Control, J-DSMC (1988-93), Editor-in-Chief of the IEEE/ASME Transactions on Mechatronics (1997-99), and Associate Editor of the Journal of the International Federation of Automatic Control (IFAC), Automatica. He served as President of the American Automatic Control Council (AACC) (1998-99), and he currently chairs the IFAC Technical Committee on Mechatronic Systems. He is a Fellow of the ASME, the Institute of Electric and Electronics Engineers (IEEE), IFAC and the Society of Manufacturing Engineers. He is the recipient of the J-DSMC Best Paper Award (1995, 2010), the DSCD Outstanding Investigator Award (1996), the Charles Russ Richards Memorial Award (ASME, 1997), the Rufus Oldenburger Medal (ASME, 2002) and the John R. Ragazzini Award (AACC, 2006).
Motion control with nanoscale precision typically requires a combination of accurate sensing and actuator technology and limited uncertainty in the dynamical behavior and vibrations to design a high performance motion control system. Even for an idealized motion system, limitations on control bandwidth and uncertainties in disturbance spectra limit the achievable performance. To maximize motion control performance one needs to exploit the freedom in both feedforward and feedback algorithms to achieve accurate positioning given limitations on the actuator control signals. A properly designed feedforward algorithm can decide what reference signals should be used for optimal trajectory planning.

In this talk we will review and demonstrate new developments in optimal trajectory planning via the design of optimal reference and feedforward signals. Optimal signals can be computed for closed-loop discrete-time linear time invariant (LTI) system, where control signals are subjected to linear constraints on amplitude and rate of change. We demonstrate the techniques for nano-positioning control in a hard disk drive, where both radial and longitudinal displacements of a read head are controlled. It is shown that nanoscale motion control can be obtained by relying on predictable system behavior and the computation of optimal input signals for motion planning.

**Biography**

Raymond A. de Callafon received the M.Sc. and Ph.D. degrees in mechanical engineering from the Delft University of Technology, Delft, The Netherlands, in 1992 and 1998, respectively. From 1997 to 1998, he was a Research Assistant with the Structural Systems and Control Laboratory in the Mechanical and Aerospace Engineering Department, University of California at San Diego, La Jolla. Since 1998, he has been a Professor with the Dynamic Systems and Control Group, University of California at San Diego. His research interests include topics in the field of control relevant system identification, structural damage detection, (linear) feedback control design, model/controller reduction and identification, and real-time control problems applied to high-precision data storage systems and active noise and vibration control applications.
The volume of digital data produced each year is growing at an ever-increasing pace. Moreover, new regulatory requirements imply that a larger fraction of this data will have to be preserved. All of this translates into a growing need for cost-effective digital archives. State-of-the-art commercial linear-tape products achieve an areal storage density of about 3 Gb/in² and a cartridge capacity on the order of four terabytes. Future scaling of the low-cost and therefore attractive solutions would require a dramatic increase in track density, which in turn implies nanoscale positioning of the head read/write transducers of a tape drive. In my talk, I will discuss the importance of nanopositioning for achieving high areal densities. Specifically, the state of the art and advances in high-bandwidth actuators, servo format and servo channel designs, and control schemes that could bring the position error signal below 20 nm, thereby enabling high track densities and cartridge capacities, will be reviewed.

Biography

Dr. Eleftheriou received the Ph.D. degree in electrical engineering from Carleton University, Ottawa, Canada, in 1985. In 1986, he joined IBM Research – Zurich in Rüschlikon, Switzerland where he currently manages the Storage Technologies Department, which focuses on phase-change memories, scanning-probe techniques and metrology, as well as tape drive technology and solid-state drive technology and systems.

In January 2002 Dr. Eleftheriou was elected Fellow of the IEEE (Institute of Electrical and Electronics Engineers). He was co-recipient of the 2003 IEEE Leonard G. Abraham Award and co-recipient of the Eduard Rhein Technology Award in 2005. The same year, he became an IBM Fellow and was inducted into the IBM Academy of Technology. In 2009 he was co-recipient of the IEEE Transactions on Control Systems Technology Outstanding Paper Award and the IEEE Control Systems Technology Award.
We show that a systematic modern control technique such as Linear Quadratic Gaussian (LQG) control can be applied to a problem in experimental quantum optics which has previously been addressed using traditional approaches to controller design. An LQG controller is synthesized to stabilize the frequency of the cavity to the laser frequency and to reject low-frequency noise. The controller is successfully implemented in the laboratory using a dSpace DSP board. The presentation will describe the original experimental setup and more recent experimental results which are directed towards the use of a time-varying Kalman filter as part of the LQG controller to improve the locking performance of the system.

**Biography**

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. In 1985 he joined the University of New South Wales at the Australian Defence Force Academy where he is currently Scientia Professor and an Australian Research Council Federation Fellow in the School of Information Technology and Electrical Engineering. He has served as an Associate Editor for the IEEE Transactions on Automatic Control, Systems and Control Letters, Automatica, and SIAM Journal on Control and Optimization. Currently he is an Editor for Automatica. He is a fellow of the IEEE. His main research interests are in robust control theory, quantum control theory and stochastic control theory.
The quality (Q) factor of the atomic force microscope micro-cantilever influences both the maximum scan speed and the image quality when operating in tapping mode. In this paper, we propose two new approaches to Q-factor control in AFM micro-cantilevers and explain how the Q factor can be changed as needed. The first method is based on the idea of piezoelectric shunt control, whereby the mechanical damping of a piezoelectric self-actuating micro-cantilever is controlled by applying an electrical impedance to the piezoelectric transducer. The second method is based on using a feedback controller with strictly negative imaginary transfer function, which is known to result in a very robust feedback loop due to the collocated nature of the micro-cantilever transfer function.

**Biography**

Reza Moheimani received a Ph.D. in electrical engineering from University of New South Wales at the Australian Defence Force Academy, Canberra, Australia in 1996. Since 1997 he has been with the University of Newcastle, Australia, where he is currently a Professor and Australian Research Council Future Fellow in the School of Electrical Engineering and Computer Science. He is the founder and director of Laboratory for Dynamics and Control of Nanosystems, a multi-million-dollar state-of-the-art research facility dedicated to the advancement of nanotechnology through innovations in systems theory and control engineering.

He has served on the editorial boards of a number of journals, including IEEE Transactions on Control Systems Technology, IEEE/ASME Transactions on Mechatronics and Control Engineering Practice. He is a recipient of the 2007 IEEE Transactions on Control Systems Technology Outstanding Paper Award and the 2009 IEEE Control Systems Technology Award. He is a Fellow of IEEE, a Fellow of IFAC and a Fellow of the Institute of Physics. His current research interests include applications of control and estimation in nanoscale positioning systems for high-speed scanning probe microscopy, control of microactuators in MEMS and emerging data storage systems.
Real-time Quantitative Estimation of Material Properties at the Nanoscale

Murti V. Salapaka
Electrical and Computer Engineering Department
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In this talk, a method of imaging is developed, where during tapping-mode operation, equivalent resonant frequency and quality factor can be obtained in real time. It involves exciting the cantilever near its resonant frequency and two other frequencies chosen close to the resonant frequency. It is shown that changes in equivalent cantilever parameters can be registered for topography changes that are less than 1 nm in height and within 400 μs of the change occurring. The estimation time is two orders of magnitude better than current techniques. This method is used to subsequently extract local dissipative and elastic properties of polymer material. Extensions that involve multi-frequency excitation and multi-modes methods will be discussed.

Biography

Professor Salapaka is in the area of Control and Dynamical Systems. He obtained his Bachelors degree in Mechanical Engineering from Indian Institute of Technology, Madras in 1991. He obtained his Masters and PhD. degrees from University of California, Santa Barbara in the years 1993 and 1997 respectively. He was at Electrical Engineering department at Iowa State University from 1997-2007. He is currently a faculty in the Electrical and Computer Engineering Department at University of Minnesota at Minneapolis. He is the recipient of the NSF CAREER Award for the year 1998.
The atomic force microscope (AFM) has been one of the quintessential instruments for nanoscale science and engineering over the past two decades. Enhancing the imaging resolution, the imaging throughput and the ability to discern material properties is an active area of research in the field of AFM.

In the first part of the talk, I will talk about some recent progress made in sensing of cantilever deflection signal in an AFM using non-optical means. Some of these sensing schemes also have the potential for multi-resolution imaging. Besides deflection sensing, there is a significant need for reliable electrical sensing with high spatial resolution. I will present some recent innovations in this field that include the use of silicide probes and encapsulated silicide probes. Also presented will be the use of normal force modulation for enhanced electrical sensing.

In the second part of the talk, I will present some experimental and analytical tools for quantitative multi-frequency AFM. Micro-cantilevers with integrated actuators and conductive probes, possessing a unique geometry, are presented. Also presented is a new modeling framework. Finite element simulations are used to gain insight into the unique dynamics of these cantilevers. The system components are experimentally identified and they show excellent match with finite element models. The proposed modeling framework was validated with experimental observations. Also presented are some imaging results.

**Biography**

Abu Sebastian was born in Kerala, India in 1977. He received the B. E. (Hons.) degree in Electrical and Electronics Engineering from BITS Pilani, India in 1998 and the M. S. and Ph. D. degrees in Electrical Engineering from Iowa State University in 1999 and 2004 respectively. He is currently a Research Staff Member at IBM’s Zurich Research Laboratory in Rüschlikon, Switzerland. His research is focussed on dynamics and control at the nanometer scale. Research interests include microcantilever-based devices and enabling technologies like nanometer-scale sensing and nanopositioning. Other research interests include novel memory concepts like probe-based storage and phase change memory.

Dr. Sebastian is a co-recipient of the 2009 IEEE Control Systems Technology Award and the 2009 IEEE Transactions on Control Systems Technology Outstanding Paper Award. He is a vice-chair of the IFAC technical committee on mechatronics and serves on the editorial board of the journal Mechatronics. He is a senior member of the Institute of Electrical and Electronics Engineers (IEEE) and a member of the American Physical Society (APS).
This talk presents a new dynamic mode of operation in an Atomic Force Microscope (AFM) where the deflection signal is used for force regulation instead of its derivatives such as the amplitude and phase. This mode is especially useful in the light of new advances that have resulted in high speed positioning systems with bandwidths of the order of one-tenth to a half of the natural frequency of the scanning probe. We formulate this problem in an optimal control setting and employ multiobjective optimization techniques to design the regulating controller. Also, we present a method to estimate the tip-sample interaction force and extract the sample topography information from this estimate. The overall scheme facilitates high speed imaging that can potentially exploit fast scanning devices without compromising on the bandwidth and resolution.

**Biography**

Prof. Salapaka received the B.Tech. degree in Mechanical Engineering from Indian Institute of Technology at Chennai, India in 1995, the M.S. and the Ph.D. degrees in Mechanical Engineering from the University of California at Santa Barbara, U.S.A in 1997 and 2002, respectively. During 2002-2004, he was a postdoctoral associate in the Laboratory for Information and Decision Systems, Massachusetts Institute of Technology, Cambridge, USA. He joined the department of Mechanical Science and Engineering at the University of Illinois, Urbana-Champaign in January 2004. He is a recipient of 2005 National Science Foundation CAREER award.
The dynamic properties of nanomechanical devices underpin numerous applications in sensing, force measurements and imaging. Due to its relevance to biological and colloidal systems and sensing applications, there is interest in the application of dynamic AFM methods to the quantitative determination of forces in fluid environments. In this talk, I will give an overview of recent work in my group dealing with the behaviour of nanomechanical devices in the presence of fluid. The first part will discuss recent developments focusing on cantilever sensors with embedded microfluidic channels, which display dramatic reduction in energy dissipation, i.e., enhanced quality factor. The underlying physical mechanisms behind this phenomenon will be presented. Second, I will discuss theoretical work aimed at exploring the behaviour of cantilever devices immersed in fluid that are operating in their higher-order modes. This inherently accounts for the three-dimensional flow generated by such devices. Finally, I will present work dealing with the effect of surface stress on the stiffness of cantilever sensors. These exhibit fundamentally different behaviour to the commonly assumed axial force model, as I will discuss. These works are aimed at developing a theoretical framework for quantitative measurements using cantilever sensors in fluid environments.

**Biography**

John E. Sader is a Professor in the Department of Mathematics and Statistics, University of Melbourne, Australia. He leads an interdisciplinary theoretical group studying a range of topics including the dynamic response of nanoparticles under femtosecond laser excitation, mechanics of nanoelectromechanical devices, high Reynolds number flow of thin films and rarefied gas dynamics in nanoscale systems.