2013 ASME Dynamic Systems and Control Conference

Stanford University, Munger Center
Palo Alto, CA
October 21-23, 2013

Sponsoring Organization

American Society of Mechanical Engineers
Dynamic Systems and Control Division

CONFERENCE ORGANIZERS AND VOLUNTEERS

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WELCOME MESSAGE FROM THE GENERAL CHAIR

Dear Attendees,

On behalf of our Organizing Committee, I wish to relay my warmest welcome to all of you at the sixth annual Dynamic Systems and Control Conference, DSCC 2013. It feels like yesterday when I (as the Executive Committee Chair then) and Galip Ulsoy stood up at the podium at the IMECE 2005 in Orlando during our Division meeting and presented a plan for a first DSCC to take place in Ann Arbor. After much debate and expressed skepticism for the health of such a move the proposition was tabled with a favorable straw vote. Further progress was left in the hands of an advisory committee of four (Galip Ulsoy, Masayoshi Tomizuka, Wayne Book and I as the Chair) which turned thumbs-up for the event and here we are at the sixth repetition of it. A number of very nice things happened in between and we are very happy to report some exciting events at this year's DSCC 2013.

Let me start with the venue selection: Stanford University's Munger Center. We are returning to a University setting for the second time since the DSCC 2008 (University of Michigan). There are numerous benefits of being in the midst of a vibrant intellectual setting for the DSCC as opposed to a professional hotel environment. Being next to the home offices of local arrangements group and the comfort this brings for remediating the emerging needs, already negotiated and relatively hassle-free catering, no hotel-room commitments etc. Of course such benefits could not come with some handicaps, such as the room limitations. But this fledgling conference is maturing, and experimenting is a way of maturing with confidence. DSCC is meant to be a volunteer-run conference, and as expected, volunteer organizers are on a continuous learning curve which is very healthy. We are accumulating the learned lessons as we move forward and it is the arsenal we are trying to build upon.

The DSCC 2013 is supporting about 300 papers this year, without a partner symposium or conference. This practically ends the earlier fear of diminishing interest from the community after our departure from IMECE. I am also proud to report that we have attracted researchers from 24 different nations at the original submissions thanks to the concerted effort of Bruno Siciliano (our International Activities Chair) who was able to bring a considerable participation from the robotics community. DSCC has become "international" in true sense of the word !

This year, we are presenting to the attendees several new features in DSCC:

(a) A single-track experimental session, during which a group of our members will demonstrate their research results on a table top setting. At DSCC 2013 we will have five such experiments on display.
(b) We have just instituted two Conference Best Paper Awards (one for theory and one for practice). They are different than our traditional student best paper awards, and the selection process started from the Editorial Board Review Reports on the submissions and finalized by a three-member jury.
(c) The registration fee will cover almost all meals and coffee breaks as well as open bar whenever we get the chance. The aim is to return as much as possible to the creators of this conference, you, the participants.

This year we have arranged for two plenary talks in addition to the Nyquist Lecture of **Galip Ulsoy** (organized by the Division). The first is by one of our senior members, and former Division Chair **Joseph Beaman** of UT Austin**.** He is going to tell us the intrigues on the topic which is attracting much national attention in the recent days: the Additive Manufacturing. The second plenary lecture will be delivered by **Oussama Khatib**, who is a well-recognized Stanford faculty. His talk will be on the recent frontiers of robotics field, and human-robot interactions. Both plenary speakers are coveted invitees to international forums and we are very happy to have them with us at the DSCC 2013.

You will also notice a separate Awards Ceremony which is going to host a special presentation by **Graham Goodwin**, the Oldenburger Awardee this year. After this ceremony we will transition into the conference banquet. We are experimenting this format for the first time so that the banquet and the awards ceremony will not interfere each other.

Once again, we will appreciate your comments on any part of the activities. The Organizing Committee is completely sensitized on the fact that the responsibility of making DSCC 2013 a memorable event is sacrosanct. Wherever we fail to fulfill your expectations, we would like to know as soon as possible, please, with the hope to recover from the mishaps.

I wish to close with a sincere declaration of appreciation to each and every one of our Organizing Committee members, and other volunteers who sacrificed from their own personal endeavors and made this event possible.

Welcome and enjoy YOUR DSCC 2013!

With warmest greetings,

Nejat Olgac
General Chair for DSCC 2013

WELCOME MESSAGE FROM PROGRAM CHAIR

Dear Colleagues,

I wish to cordially welcome you to the sixth Dynamic Systems and Controls Conference (2013 DSCC). This year DSCC heads to one of the world's epicenters of academic, scientific, and entrepreneurial activity—Stanford University in the majestic and breathtaking Northern California.

This year's program includes 290 papers, selected from 406 submissions, making for a 72% acceptance rate.

The papers are distributed in 49 sessions, of which 29 sessions are contributed and 20 are invited. I thank the technical committees and individuals for the initiative in assembling such a high number of invited sessions and attracting many authors to attend DSCC for the first time.

Numerous volunteers have contributed to the construction of the technical program. I would like to extend special thanks to the associate editors on the Conference Editorial Board, the reviewers, the emergency reviewing teams at University of Connecticut and UC San Diego, General Chair Nejat Olgac in his advisory role as an experienced past PC chair, and, most of all, the CEB chair Dave Bevly whose help in the post-editorial process was crucial for assembling the program.

The conference provides a rich set of keynote lectures, consisting of the Nyquist lecture by Professor Galip Ulsoy, the Oldenburger award lecture by Professor Graham Goodwin, the plenary lecture on 3D printing by Professor Joseph Beaman from University of Texas at Austin, and a plenary lecture on robots and the human by Professor Oussama Khatib of Stanford University.

I wish you productive and pleasant days of learning, disseminating your results, networking, and socializing at DSCC13!

Miroslav Krstic
Program Chair of DSCC2013
University of California, San Diego

CONFERENCE INFORMATION AND PROGRAM HIGHLIGHTS

Conference-at-a-Glance

(Details can be found at
http://asme-dscd.papercept.net/conferences/conferences/DSC13/program/DSC13_ProgramAtAGlanceWeb.html)

	Monday						
	Track 1	Track 2	Track 3	Track 4	Track 5	Track 6	Track 7
Track Rooms	**Paul Brest East**	**Room 123**	**Tent A**	**Paul Brest West**	**Tent B**	**Room 134**	**Room 138**
8:30 - 9:30	Plenary Session - (Paul Brest Hall)-Joseph Beaman						
9:30 - 10:15	Breakfast Break						
10:15 - 12:15	Session MoAT1	Session MoAT2	Session MoAT3	Session MoAT4	Session MoAT5	Session MoAT6	Session MoAT7
12:15 - 13:30	Lunch - Tutorial (Stochastic Processes)						
13:30 - 15:30	Session MoBT1	Session MoBT2	Session MoBT3	Session MoBT4	Session MoBT5	Session MoBT6	Session MoBT7
15:30 - 16:00	Coffee Break						
16:00 - 17:00	Session MoCT1	Session MoCT2	Session MoCT3	Session MoCT4	Session MoCT5	Session MoCT6	Session MoCT7
17:00 - 18:00							
18:00 - 18:30	Welcome Reception						
18:30 - 19:00							
19:00 - 20:00							
20:00 - 21:30	ExCom-General Mtg.						

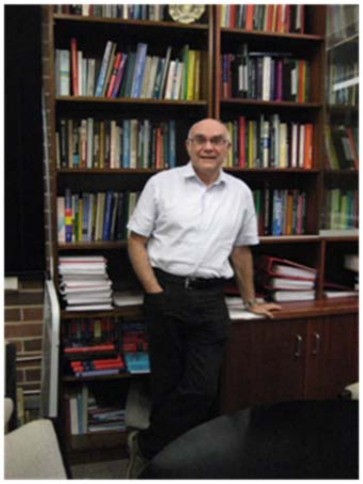
	Tuesday						
	Track 1	Track 2	Track 3	Track 4	Track 5	Track 6	Track 7
Track Rooms	**Paul Brest East**	**Room 123**	**Tent A**	**Paul Brest West**	**Tent B**	**Room 134**	**Room 138**
8:30 - 9:30	Nyquist Lecture-(Paul Brest Hall)-Galip Ulsoy						
9:30 - 10:15	Breakfast Break						
10:15 - 12:15	Session TuAT1	Session TuAT2	Session TuAT3	Session TuAT4	Session TuAT5	Session TuAT6	Session TuAT7
12:15 - 13:30	Lunch - Tutorials (Modeling)						
13:30 - 15:30	Session TuBT1	Session TuBT2	Session TuBT3	Session TuBT4	Session TuBT5	Session TuBT6	Session TuBT7
15:30 - 16:00	Experimental Session - refreshments						
16:00 - 17:00							
17:00 - 18:00	Award Ceremony Oldenburger Lecture-Graham Goodwin						
18:00 - 18:30							
18:30 - 19:00	Break						
19:00 - 20:00	Banquet (@ McCaw Alumni Center-Munger)						
20:00 - 21:30							

	Wednesday						
	Track 1	Track 2	Track 3	Track 4	Track 5	Track 6	Track 7
Track Rooms	**Paul Brest East**	**Room 123**	**Tent A**	**Paul Brest West**	**Tent B**	**Room 134**	**Room 138**
8:30 - 9:30	Plenary Session-(Paul Brest Hall) -Oussama Khatib						
9:30 - 10:15	Breakfast Break						
10:15 - 12:15	Session WeAT1	Session WeAT2	Session WeAT3	Session WeAT4	Session WeAT5	Session WeAT6	Session WeAT7
12:15 - 13:30	Lunch - Grants at NSF						
13:30 - 15:30	Session WeBT1	Session WeBT2	Session WeBT3	Session WeBT4	Session WeBT5	Session WeBT6	Session WeBT7
15:30 - 16:00	Farewell Reception - 15:30-17:30						
16:00 - 17:00							
17:00 - 18:00							
18:00 - 18:30							
18:30 - 19:00							
19:00 - 20:00							
20:00 - 21:30							

DSCD Awards and Awards Ceremony

Time: **5:00 pm – 6:30 pm, Tuesday, October 22, 2013**
Location: Paul Brest Hall

2013 Oldenburger Award and Lecture



Title: "Beyond Servo Mechanisms: Challenges and Opportunities in Control Science"

Prof. Graham C. Goodwin
BSc, BE, PhD, FRS, FIEEE, Hon.FIE.Aust., FTSE, FAA
Federation Fellow and Professor of Electrical Engineering
Centre f or Complex Dynamic Systems and Control
School of Electrical Engineering and Computer Science
The University of Newcastle
Callaghan NSW 2308, AUSTRALIA

Abstract: In common with many control engineers, my early career focused on traditional applications of control in industry including rolling mills, robotic systems, continuous casting machines and sugar mills. In recent years, I have turned to new areas of application including

- Improving the uplink data rate in 3G and 4G mobile telecommunication systems,
- Scheduling ambulances to improve the efficiency of emergency services, and
- Developing an artificial pancreas.

Many of the well tried ideas in control are immediately applicable to these problems. However, new challenges and opportunities also arise. In this talk I will give an introduction to some of these new issues and argue that systems and control science will continue to be a vibrant and exciting field for many years to come.

Biography: Graham Goodwin graduated from the University of New South Wales with B.Sc. (Physics) 1965, B.E. Honours I (Electrical Engineering) 1967 and Ph.D. 1971. In 2010 he was awarded the IEEE Control Systems Field Award. Other international awards include the 1999 IEEE Control Systems Society Hendrik Bode Lecture Prize, a Best Paper award by IEEE Transactions on Automatic Control, a Best Paper award by Asian Journal of Control, and two Best Engineering Text Book awards from the International Federation of Automatic Control in (1984 and 2005). He received the 2008 Quazza Medal from the International Federation of Automatic Control, the 2010 Nordic Process Control Award, and the 2011 Asian Control Association Wook Hyun Kwon Education Award. He is a Fellow of IEEE; an Honorary Fellow of Institute of Engineers, Australia; a Fellow of the International Federation of Automatic Control, a Fellow of the Australian Academy of Science; a Fellow of the Australian Academy of Technology, Science and Engineering; a Member of the International Statistical Institute; a Fellow of the Royal Society, London and a Foreign Member of the Royal Swedish Academy of Sciences. He holds Honorary Doctorates from Lund Institute of Technology, Sweden and the Technion Israel. He is the co-author of nine books, four edited books, 218 international journal papers and 322 refereed international conference papers. He has successfully supervised 38 Ph.D. students. He has presented 60 Keynote Addresses at major international conferences. Graham is a Distinguished Professor at Harbin Institute of Technology (China), Northwestern University (China), Zhengzhou University (China) and Universidad Técnica Federico Santa María (Chile). He holds 16 International Patents covering rolling mill technology, telecommunications, mine planning and mineral exploration.

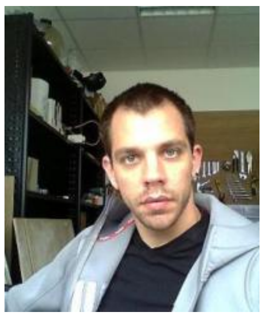
FINALISTS OF DSCC 2013 BEST PAPER AWARDS AND BEST STUDENT PAPER AWARDS

Best Conference Paper Awards Finalists

Best Paper Award Finalists in Theory:

Title: A Feed Forward Neural Network for Solving the Inverse Kinetics of Non-Constant Curvature Soft Manipulators Driven by Cables
Authors: Mr. Michele Giorelli, Dr. Federico Renda, Dr. Gabriele Ferri, Dr. Cecilia Laschi, Research Centre on Sea Technologies and Marine Robotics, The BioRobotics Institute, Scuola Superiore Sant'Anna, Pisa, 56127, Italy


Michele Giorelli


Federico Renda


Gabriele Ferri


Cecilia Laschi

Title: Equivalency of Stability Transitions Between the SDS (Spectral Delay Space) and DS (Delay Space)
Authors: Mr. Qingbin Gao, Mr. Umut Zalluhoglu, and Dr. Nejat Olgac, Mechanical Engineering, University of Connecticut, Storrs, CT 06269, USA.


Qingbin Gao


. Umut Zalluhoglu


Nejat Olgac

Title: Output-Boundary Regulation: High-Speed AFM Imaging Application
Authors: Mr. Arom Boekfah and Dr. Santosh Devasia, Department of Mechanical Engineering, University of Washington. Seattle, Washington 98195

Arom Boekfah Santosh Devasia

Best Paper Award Finalists in Applications:

Title: Optimal Compression of a Generalized Prandtl-Ishlinskii Operator in Hysteresis Modeling
Authors: Mr. Jun Zhang, Mr. Emmanuelle Merced, Dr. Nelson Sep´ulveda, and Dr. Xiaobo Tan, Smart Microsystems Laboratory, Department of Electrical and Computer Engineering, Michigan State University, East Lansing, Michigan 48824

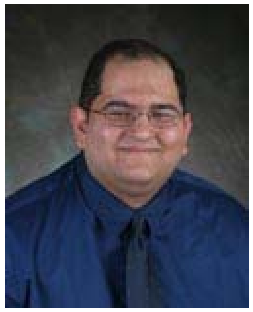
Jun Zhang, Emmanuelle Merced Nelson Sep´ulveda Xiaobo Tan

Title: Semi-Active Control Methodology for Control of Air Spring-Valve -Accumulator System
Authors: Dr. William D. Robinson, John Deere Intelligent Solutions Group Urbandale, Iowa 50322, Dr. Atul G. Kelkar, Mechanical Engineering Department, Iowa State University, Ames, Iowa 50011, and Dr. Jerald M. Vogel, IVS, Inc., Ames, Iowa 50010

William D. Robinson Atul kelkar Jerald Vogel

Title: Battery State of Health and Charge Estimation Using Polynomial Chaos Theory
Authors: Mr. Saeid Bashash and Dr. Hosam K. Fathy, Department of Mechanical and Nuclear, Engineering Pennsylvania State University, University Park, PA 16802, USA

Saeid Bashash



Hosam K. Fathy

Student Best Paper Award Finalists:

Title: Equivalency of Stability Transitions Between the SDS (Spectral Delay Space) and DS (Delay Space)
Authors: Mr. Qingbin Gao, Mr. Umut Zalluhoglu, and Dr. Nejat Olgac, Mechanical Engineering, University of Connecticut, Storrs, CT 06269, USA.

Qingbin Gao

. Umut Zalluhoglu

Nejat Olgac

Title: Battery Health Diagnostics Using Retrospective-Cost Subsystem Identification: Sensitivity to Noise and Initialization Errors
Authors: Ms. Xin Zhou, Dr. Tulga Ersal, Dr. Jeffrey L. Stein, Department of Mechanical Engineering, and Dr. Dennis S. Bernstein, Department of Aerospace Engineering, University of Michigan, Ann Arbor, Michigan 48109

Xin Zhou

Tulga Ersal

Jeffrey L. Stein

Dennis S. Bernstein

Title: Online Simultaneous State Estimation and Parameter Adaptation for Building Predictive Control

Authors: Mr. Mehdi Maasoumy, Department of Mechanical Engineering, University of California Berkeley, California 94720, USA, Mr. Barzin Moridian, Mr. Meysam Razmara, Dr. Mahdi Shahbakhti, Mechanical Engineering-Engineering Mechanics Department, Michigan Technological University, Houghton, Michigan 49931-1295, and Dr. Alberto Sangiovanni-Vincentelli, Department of Electrical Engineering and Computer Sciences, University of California, Berkeley, California 94720-1770


Mehdi Maasoumy


Barzin Moridian,


Meysam Razmara,


Mahdi Shahbakhti


Alberto Sangiovanni-Vincentelli

Title: Precision Control Through Vibration Suppression in Piezoelectric-Stepper Response

Authors: Mr. Scott Wilcox and Dr. Santosh Devasia, Department of Mechanical Engineering, University of Washington, Seattle, Washington 98195.


Scott Wilcox


Santosh Devasia

Title: Energy-Based Limit Cycle Compensation for Dynamically Balancing Wheeled Inverted Pendulum Machines

Authors: Mr. Hari Vasudevan, Dr. Aaron M. Dollar, and Dr. John B. Morrell, Department of Mechanical Engineering and Materials Science, Yale University, New Haven, Connecticut, 06511

Hari Vasudevan

Aaron M. Dollar

John B. Morrell

Social and Special Programs

Welcome Reception

Time: 6:00 pm – 8:00 pm, Monday, October 21, 2013
Location: Conference site

Meet conference participants and enjoy delicious food and drinks. Please wear your registration badge and bring a welcome reception ticket involved in the registration packet.

Student, Young Professional, and Newcomer Orientation

Time: 12:15 pm – 1:30 pm, Monday, October 21, 2013
Location: Paul Brest Hall

Industry-Student CV Speed Dating

Time: 6:00 pm – 7:30 pm, Monday, October 21, 2013
Location: Paul Brest Hall

Conference Banquet (following the Awards Ceremony)

Time: 7:00 pm – 9:30 pm, Tuesday, October 22, 2013
Location: Conference site

Farewell Reception

Time: 3:30 pm – 5:30 pm, Wednesday, October 23, 2013
Location: Conference site

Immediately after the final sessions, the DSCC Farewell Reception will be held. Please come celebrate the DSCC conference.

Breakfast Breaks

Times: 9:30 am – 10:15 am, Monday, Tuesday, Wednesday
Location: Conference site

Lunch Breaks

Times: 12:15 pm – 1:30 pm, Monday, Tuesday, Wednesday
Location: Conference site

Coffee Break

Times: 3:30 pm – 4:00 pm, Monday
Location: Conference site

PLENARY TALKS, LECTURES AND SPECIAL SESSIONS

DSCC Plenary Talk

Emerging Nexus of Cyber, Modeling, and Estimation in Advanced Manufacturing

Time: **Monday, Oct 21, 2013, 8:30 am – 9:30 am** Location: Paul Brest Hall

Joseph Beaman
Professor, Department of Mechanical Engineering
Earnest F. Gloyna Regents Chair in Engineering
The University of Texas at Austin

Professor Joseph J. Beaman's career work has been in design, manufacturing and control. His specific manufacturing research interest is in Solid Freeform Fabrication, a manufacturing technology that produces freeform solid objects directly from a computer model of the object without part-specific tooling or knowledge. Dr. Beaman coined this term in 1987. Professor Beaman initiated research in the area in 1985 and was the first academic researcher in the field. One of the most successful Solid Freeform Fabrication approaches, Selective Laser Sintering, was a process that was developed in his laboratory. In particular, he has worked with graduate students, faculty, and industrial concerns on the fundamental technology that span materials, laser scanning techniques, thermal control, mold making techniques, direct metal fabrication, and biomedical applications. Besides his work in Solid Freeform Fabrication, Professor Beaman has worked extensively with the special metals processing industry to develop next generation process control for remelting processes that are used to produce special metals alloys such as super alloys and titanium alloys. Professor Beaman has pioneered the use of high fidelity physics-based models in real-time manufacturing process control in order to estimate and control important outputs in these remelting processes. In many cases, it would not have been possible to estimate and control these outputs without detailed models of the processes. Dr. Beaman has BS and MS degrees from UT Austin, and PhD from MIT. He is a Fellow of the American Society of Mechanical Engineers. He serves on the Army Science Board and Board of Directors of Society of Manufacturing Engineers and was Chair of the Department of Mechanical Engineering at the University of Texas from 2001 to 2012. He was elected to the National Academy of Engineers in February 2013.

Abstract:
There have been tremendous advances in three important technical areas in the last decade: computing capability, physics-based modeling, and estimation methods. Although these advances are well known in the research community, they have not been deployed to any great extent in the manufacturing industry. It is become increasingly clear that manufacturing is of fundamental importance to the vitality of the US economy. Small lot or small volume manufacturing, which are often high value products, offers a unique opportunity to open up fundamentally new business for manufacturers. One of the major challenges to successful small lot manufacturing is the cost of qualifying and certifying that the product meets its design specifications. This is substantially the function of manufacturing process control. Contemporary process control is statistic-based and is most effective for large volume manufacturing. Such process control is not effective if the conditions or the product changes, such as occurs in small lots.

This talk will describe opportunities for exploiting these three technical areas for advanced manufacturing in small lots. Potential application in an emerging manufacturing process, Additive Manufacturing, and a potential application in a mature manufacturing process, Vacuum Arc Remelting, will be highlighted. In particular, a process for Cyber Enabled Manufacturing (CeMs) process control for small lot

manufacturing that incorporates a model of the process directly into the control algorithm. Such a model can be used to accommodate changes in the physical product and the manufacturing process and thus the manufacturing monitoring and control algorithm, so that changing conditions are easily accommodated without extensive additional experiments. A set of objectives of this physics and cyber-enabled manufacturing process control system are rational setting of manufacturing tolerances, real time prediction of manufacturing defects, real time control of process to eliminate defects, and real time monitoring and control for small lot manufacturing. The methodologies to achieve these goals are high fidelity, physics based models including models of faults/defects, uncertainty quantification, reduced order models that run in real time, measurement, real time prediction, real time computer architecture, real time control with inverse solutions, and automating the CeMs process for generic manufacturing processes. The development of such accurate control algorithms and their application to manufacturing processes can provide a competitive edge.

DSCC Plenary Talk:

Robots and the Human

Time: **Wednesday, Oct 23, 2013, 8:30 am – 9:30 am** Location: Paul Brest Hall

Oussama Khatib
Professor of Computer Science
Artificial Intelligence Laboratory
Department of Computer Science
Stanford University

Oussama Khatib received his Doctorate degree from Sup'Aero, Toulouse, France, in 1980. He is Professor of Computer Science at Stanford University. He is the President of the International Foundation of Robotics Research, IFRR. Professor Khatib is the Co-Editor of Springer Handbook of Robotics and the Springer Tracts in Advanced Robotics series. He is a Fellow of IEEE and has served as a Distinguished Lecturer, as the Program Chair of ICRA 2000, and the General Chair of IROS 2011. He is a recipient of the Japan Robot Association (JARA) Award in Research and Development, the IEEE RAS Pioneer Award in Robotics and Automation for his fundamental pioneering contributions in robotics research, visionary leadership, and life-long commitment to the field. He has also received the IEEE RAS Distinguished Service Award in recognition of his vision and leadership for the Robotics and Automation Society, in establishing and sustaining conferences in robotics and related areas, publishing influential monographs and handbooks and training and mentoring the next generation of leaders in robotics education and research.

Abstract:
Robotics is rapidly expanding into the human environment and vigorously engaged in its new emerging challenges. From a largely dominant industrial focus, robotics has undergone, by the turn of the new millennium, a major transformation in scope and dimensions. This expansion has been brought about by the maturity of the field and the advances in its related technologies to address the pressing needs for human-centered robotic applications. Interacting, exploring, and working with humans, the new generation of robots will increasingly touch people and their lives, in homes, workplaces, and communities, providing support in services, health care, entertainment, education, and assistance. The discussion focuses on new design concepts, novel sensing modalities, efficient planning and control strategies, modeling and understanding of human motion and skills, which are among the key requirements for safe, dependable, and competent robots. The exploration of the human-robot connection

is proving extremely valuable in providing new avenues for the study of human motion -- with exciting prospects for novel clinical therapies, athletic training, character animation, and human performance improvement.

Nyquist Lecture:

Reconfigurable Systems: The Role of Dynamics and Control

Time: **Tuesday, Oct 22, 2013, 8:30 am – 9:30 am** Location: Paul Brest Hall

A selected prominent lecturer is invited to present the Nyquist Lecture each year starting with the 2005 IMECE in Orlando. The spirit is to convey the DSCD Community a message of relatively broad interest.

2013 Nyquist Lecturer

Galip Ulsoy
C.D. Mote Jr. Distinguished University Professor, Mechanical Engineering;
Professor, Mechanical Engineering;
William Clay Ford Professor of Manufacturing;
Deputy Director, NSF Engineering Research Center for Reconfigurable Machining Systems
University of Michigan

A. Galip Ulsoy is the C.D. Mote, Jr. Distinguished University Professor of Mechanical Engineering and the William Clay Ford Professor of Manufacturing at University of Michigan, Ann Arbor. He received the Ph.D. from University of California at Berkeley (1979), the M.S. degree from Cornell University (1975), and the B.S. degree from Swarthmore College (1973). His research interests are in the dynamics and control of mechanical systems. He has received numerous awards, including the American Automatic Control Council's 1993 O. Hugo Schuck Best Paper Award, the 2003 Rudolf Kalman Best Paper Award from the *J. Dynamic Systems, Measurement and Control,* the 2008 Albert M. Sargent Progress Award from the Society of Manufacturing Engineers (SME), the 2008 Rufus T. Oldenburger Medal and the 2013 Charles Russ Richards Award from the American Society of Mechanical Engineers (ASME). He is a member of the US National Academy of Engineering, received the 2012 Presidential Special Award from the Scientific and Technological Research Council of Turkey, and is a Fellow of ASME, SME and the International Federation of Automatic Control (IFAC).

Abstract:
We live in an engineered world, where technologies rapidly become obsolete, and which can easily be disrupted by external events such as world markets, disasters or political strife. Engineers need to design systems that evolve in the face of such pressures, and technologies that can be reconfigured to the new circumstances. This talk introduces the principles behind reconfigurable manufacturing systems (RMS), which provide exactly the manufacturing functionality and capacity needed, exactly when needed. Examples are presented to highlight the role that dynamics and control plays in designing systems to be more reconfigurable. These examples include optimal capacity management in an RMS, dynamics of a reconfigurable machine tool, a smart boring bar that senses and corrects for boring bar vibrations, a networked control system to coordinate machine tool axis modules, a reconfigurable stamping control system, as well as methods for co-design of an artifact and its controller and for component swapping modularity in controller design. The talk concludes with some speculations on the future of reconfigurable systems.

Past Nyquist Lecturers and Titles of Presentations

2005 – Karl Astrom: *Nyquist and his Seminal Papers*
2006 – George Leitmann: *A Transformation-Based Optimization Method*
2007 – Art Bryson: *Flight Guidance and Control in Strong Winds*
2008 – Masayoshi Tomizuka: *Control Theory in Mechatronics, Necessary but not Sufficient*
2009 – Karl Hedrick: *Vehicle Dynamics Systems: From Automation to Autonomy*
2010 – Wayne Book: *Cold Cases and Hot Topics*
2011 – Mathukumalli Vidyasagar: *Four Decades of Control: A Journey of Reinventions*
2012 – Manfred Morari: *Fast Model Predictive Control*

Special/Tutorial Sessions

We have arranged for several lunch-hour tutorial sessions during the lunch breaks.

Tutorial Session: Stochastic Processes, Kalman Filtering and Stochastic Control

Time: **Monday, Oct 21, 2013, 12:25 pm – 1:25 pm**
Location: Conference site

Prof. Dejan Milutinović, University of California at Santa Cruz

Abstract: The aim of this tutorial is to introduce the concept of stochastic differential equations, associated calculus and its implications to optimal estimation and control theory. Instead of using abstract mathematical definitions, we use an approach directed towards the application of stochastic differential equations to modeling real dynamical processes, which is closer to the original motivations for this type of differential equations.

To emphasize applications, the tutorial starts with an analysis of dynamical systems with state transitions resulting from micro-scale continuous time stochastic discrete event processes. We use it to show that a stochastic differential equation model is strongly related to its specific spatio-temporal scale and parameters, and that there is need for the so-called process noise, which is the concept used in the definition of the Kalman filter.

The Kalman filter is presented in the time domain and, in the most general way, through the prediction and update steps of the state probability density function. The emphasis is not so much on the widely known set of matrix expressions, but on concepts involved in the prediction and update steps, i.e., Fokker-Planck equation and Bayes theorem. Most importantly, the relation between the so-called Kalman smoother and control problems is introduced and illustrated by an example from robotics.

Well-defined models and uncertainty resulting from possible robot actions make robots and multi-robot systems a well fit for applications and the development of stochastic optimal control theory. Fundamental principles defining solutions of open- and closed-loop optimal control, and numerical solutions are presented in the last part of the tutorial.

This tutorial is of interest to any researcher who wants to have a jump start into stochastic modeling and the control of dynamical systems. Examples in the tutorial are motivated by research in biology and robotics, but no specialized knowledge is necessary for their understanding.

Speaker bio: Dr.-Ing. Dejan Milutinović is an Assistant Professor at Baskin School of Engineering, UC Santa Cruz. He earned Dipl.-Ing. (1995) and Magister's (1999) degrees in Electrical Engineering from the University of Belgrade, Serbia and a doctoral degree in Electrical and Computer Engineering (2004) from Instituto Superior Tecnico, Lisbon, Portugal. His thesis was voted for the first runner-up for the best PhD thesis of European Robotics in 2004 by EURON, a network of over 150 European robotics research groups. He won the National Research Council Award of the US academies in 2008. He held postdoctoral fellow positions in immunology for four years, followed by one year in the area of robotics at Utrecht University, the Netherlands and Duke University. Dr. Milutinović pursues research in the area of modeling and control of stochastic dynamical systems applied to robotics and biology. He is the first author of the research monograph "Cells and Robots", Springer, 2007, and the co-editor of the volume "Redundancy in Robot Manipulators and Multi-Robot Systems", Springer, 2013. For more details see: http://people.ucsc.edu/~dmilutin/.

Special Session: Modeling and Simulation: What are the Fundamental Skills and Practices to Impart to our Students?

Time: **Tuesday, Oct 22, 2013, 12:25 pm – 1:25 pm**
Location: Conference site

Session Organizer and Moderator: **Prof. Jeffrey L. Stein**, University of Michigan

For decades modeling and simulation has been developed and promoted as an engineering tool of great potential. Engineering schools have been preparing students using textbooks that have evolved relatively little during time of rapid growth and use of modeling and simulation in industry. In addition, the multi-disciplinary nature of academic research and industry products work has created a need for models in areas where fundamental building blocks are more amorphous. This special session will present provocative ideas of modeling and simulations concepts that should be part of our curriculum. Three speakers will highlights this topic from both academic and industrial perspectives. A panel session will follow to allow the audience to add their perspective through questions of the speakers.

Moderator Bio: Jeffrey L. Stein received the B.S. degree in Premedical Studies with a minor in Psychology from the University of Massachusetts, Amherst in 1973, the S.M. and S.B. degrees in Mechanical Engineering from Massachusetts Institute of Technology in 1976, and the Ph.D. degree in Mechanical Engineering from Massachusetts Institute of Technology in 1983. He is a Full Professor with the Department of Mechanical Engineering, The University of Michigan, Ann Arbor, and is the former Chair of the Dynamic Systems and Control Division of ASME. His discipline expertise is in the use of computer based modeling and simulation tools for system design and control. He has particular interest in algorithms for automating the development of proper dynamic mathematical models (minimum yet sufficient complexity models with physical parameters). His application expertise is the areas of automotive engineering including green energy transportation, machine tool design and lower leg prosthetics. In the area of green transportation he is working to develop the techniques for the design and control of plug-in hybrid vehicles and smart grid technologies that creates a more efficient use of energy, particular that generated from renewable resources, for a lower carbon and other emissions footprint. He has authored or coauthored over 160 articles in journals and conference proceedings.

Speaker #1
Title: Should we teach models or modeling?

Prof. Neville Hogan, MIT

Abstract: A primary goal of modeling (and arguably the goal) is to develop insight. Traditional methods of teaching dynamic systems modeling have emphasized "first principles" focused on specific applications—electro-mechanical, thermo-fluid, etc. As a result, we don't teach how to model; we teach a list of pre-packaged models—usually linear—and their analysis. But mechanical systems commonly exhibit non-smooth, nowhere-near-linear behavior. Nevertheless, we can use linear models to analyze and design these systems with considerable success. I submit that our teaching does not adequately address this "disconnect" and leaves our students ill-prepared to tackle novel problems.

Biological systems highlight this disconnect. Even the simplest biological system is vastly more complex than any "first-principles" method can manage. Yet they typically exhibit relatively simple behavior. I will argue that modeling should not start from "first principles" but from "what's-the-crudest-model-that-would-serve-my-purpose?" That would allow an emphasis on the problem of identifying model parameters (a strong motivation for simplicity) and provide a natural justification for linear models (they are vastly easier to analyze) yet emphasize that the "real" system is likely much more complicated. I will review an example from my own work to illustrate the benefits of this "minimalist" approach.

Speaker bio: Neville Hogan is Sun Jae Professor of Mechanical Engineering and Professor of Brain and Cognitive Sciences at the Massachusetts Institute of Technology (MIT). He received the Dip. Eng. (with distinction) from Dublin Institute of Technology, Dublin, Ireland, and M.S., M.E. and Ph.D. degrees from MIT. Following industrial experience in engineering design, he joined MIT's school of Engineering faculty in 1979 and has served as Head and Associate Head of the MIT Mechanical Engineering Department's System Dynamics and Control Division. He is Director of the Newman Laboratory for Biomechanics and Human Rehabilitation and a founder and director of Interactive Motion Technologies, Inc.

Professor Hogan's research interests include robotics, motor neuroscience, and rehabilitation engineering, emphasizing the control of physical contact and dynamic interaction. He has been awarded Honorary Doctorates from Delft University of Technology and Dublin Institute of Technology; the Silver Medal of the Royal Academy of Medicine in Ireland; the Henry M. Paynter Outstanding Investigator Award, and the Rufus T. Oldenburger Medal from the Dynamic Systems and Control Division of the American Society of Mechanical Engineers.

Speaker #2
Title: Beyond System Dynamics and State-Space
Dr. Michael Tiller, Xogeny, Inc.

Abstract: My work in industrial modeling applications has put me in the frequent position of having to "bridge the gap" between what students learn at the university level and what they need to know about model-based system engineering in an industrial context. Universities must constantly deal with the fact that there is always too much to teach and not enough time to teach it. I say this to make it clear that I am aware of this constraint and sympathetic to it.

However, there are two important shifts going on that I think educators need to keep in mind when planning the modeling and simulation curriculum for modern engineers. The first is that effective industrial modeling requires students to think beyond linearized and/or state space formulations of system dynamics. These are, of course, a great starting point and there is much that you can say and learn about a system with these approaches. But real-world applications of modeling and simulation frequently involve differential-algebraic systems, non-linearities, variable structure systems, and so on. These are hard topics to tackle, but they are increasingly important in industrial contexts and the curriculum should address them.

Another important shift has to do with the fact that advances in modeling tools and methodologies has created so many parallels with software development that we can basically view model development as a software development activity. Sure, it isn't just software development. It clearly requires a deep understanding of math, engineering and physics as well. But many of the principles, technologies and strategies that define an efficient software development strategy should be applied in engineering. As just one example, version control is an essential component of any software development process. However, most engineers know nothing about the workflow of or collaboration through a version control system. This talk will review these topics and hopefully stimulate a discussion on how they translate into a curriculum that helps prepare students for these shifts.

Speaker bio: Michael Tiller received his Ph.D. in Mechanical Engineering in 1995 from the University of Illinois at Urbana-Champaign. His interest in modeling and simulation began in high school and was a constant thread through both is undergraduate and graduate studies as well as his professional career. Following graduation, Dr. Tiller worked as a Technical Specialist in the Powertrain Research Department at Ford Motor Company. He worked extensively on the modeling of internal combustion engines and transmissions. He holds 8 patents globally derived from his work on the Ford Hybrid Escape, the first production hybrid SUV and the first North American production hybrid.

Dr. Tiller left Ford Motor Company in 2005 to because Vice-President at Emmeskay, a Michigan based engineering consulting firm. During his tenure at Emmeskay, Dr. Tiller was the technical lead on numerous consulting projects, mostly in the automotive industry, pushing the boundaries of model-based system engineering. In 2010, Emmeskay was acquired by LMS International, a Belgian company and maker of the AMESim simulation tool. In 2011, Dr. Tiller left LMS to join Dassault Systèmes in Paris as the Global Director of Marketing for their system simulation tools. He left Dassault Systèmes in 2012 to start his own company, Xogeny, which is build a platform to support web and cloud based model-based system engineering tools.

Dr. Tiller has been long been a champion for standards in the area of model-based system engineering. He has been a member of the Modelica Association board of directors for over a decade and in that role has helped develop the Modelica Language Specification, Modelica Standard Library and the Functional Mockup Interface (FMI) Specification. He also wrote the first book on Modelica in 2001 and is currently working on a follow-up book.

Speaker #3
Title: Teaching the Tools that Streamline the Modeling Process

Prof. Marcia O'Malley, Rice University

Abstract: For the past few years, I have collaborated with computer scientists to develop a core domain-specific language for modeling cyber-physical systems. We have noted that existing methods of modeling fail at providing ways of virtualizing such systems, so that simulations and experiments can be performed without the use of expensive hardware. The proposed core language, Acumen, has a small set of features, yet is expressive enough to cover prominent aspects of cyber-physical systems. Our objective is to provide a domain-specific language that will streamline the system (including control) design process and allow better characterization of hardware-based computation so that simulation will better reflect what we see in experiments. When considering the methods for teaching computational tools for modeling, students fail to realize the utility of computer simulation – either they skip the modeling step and go right to "hacking," or they overly trust the computer simulation which fails to accurately reflect limitations that arise in hardware implementation and can give false sense of security. I will discuss the computational tools and languages that make the process of modeling more streamlined and effective, and considerations for teaching these tools as the field develops.

Speaker bio: Marcia O'Malley received the B.S. degree in mechanical engineering from Purdue University in 1996, and the M.S. and Ph.D. degrees in mechanical engineering from Vanderbilt University in 1999 and 2001, respectively. In 2001 she joined the Mechanical Engineering and Materials

Science Department at Rice University, where she is currently an Associate Professor and directs the Mechatronics and Haptic Interfaces Lab. She holds a joint appointment in Computer Science at Rice, and is an Adjunct Associate Professor in the Departments of Physical Medicine and Rehabilitation at both Baylor College of Medicine and the University of Texas Medical School at Houston. Additionally, she is the Director of Rehabilitation Engineering at TIRR-Memorial Hermann Hospital, and is a co-founder of Houston Medical Robotics, Inc. At Rice, her research addresses issues that arise when humans physically interact with robotic systems, with a focus on training and rehabilitation in virtual environments. In 2008, she received the George R. Brown Award for Superior Teaching at Rice University. O'Malley is a 2004 Office of Naval Research Young Investigator and the recipient of the NSF CAREER Award in 2005. She received the Best Paper Award at the 2011 IEEE World Haptics Conference in Istanbul, Turkey. She is the former chair of the IEEE Technical Committee on Haptics and was on the founding editorial board for the IEEE Transactions on Haptics. She also served on the editorial board of the ASME/IEEE Transactions on Mechatronics.

Special Session: Updates and New Opportunities for Dynamic Systems and Control at the National Science Foundation (NSF)

Time: **Wednesday, Oct 23, 2013, 12:25 pm – 1:25 pm**
Location: Conference site

Drs. Eduardo Misawa and George Chiu, NSF

Abstract: This session will provide updates on existing disciplinary programs at the National Science Foundation (NSF) related to the Dynamic Systems and Control community. The session will also introduce opportunities that have been recently announced by NSF that maybe of interest to the DSC community, such as National Robotics Initiatives, Cyber-Physical Systems, Cyber Infrastructure Framework for the 21st Century, and cross-disciplinary funding opportunities.

Speaker bios:
Dr. Eduardo Misawa has a B.Sc. and M.Sc. degrees from University of Sao Paulo (1979 and 1983) and Ph.D. degree from the Massachusetts Institute of Technology (MIT, 1988), all in Mechanical Engineering with concentration in Dynamics and Control. He is currently a Program Director in the Directorate for Engineering at the National Science Foundation. His research experience includes Nonlinear Dynamics, Nonlinear Control, Robust Control, Vibrations, Mechatronics, Nanotechnology, Precision Engineering, Vehicle Dynamics, Fluid Power Control, Bioinformatics, Biotechnology and Biomedical Engineering. He is a member of the ASME, IEEE, ASEE, and SIAM.

Dr. George Chiu is the Program Director for the Control Systems Program in the Division of Civil, Mechanical and Manufacturing Innovation (CMMI) of the Engineering Directorate at the National Science Foundation. He is a Professor in the School of Mechanical Engineering with a courtesy appointment in the School of Electrical and Computer Engineering and the Department of Psychological Science at Purdue University. He received the B.S. degree in Mechanical Engineering from the National Taiwan University in 1985 and the M.S. and Ph.D. degrees in Mechanical Engineering from the University of California at Berkeley, in 1990 and 1994, respectively. Dr. Chiu is the Editor for the Journal of Imaging Science and Technology and an associate editor for the IFAC Journal of Control Engineering Practice. He is a Fellow of ASME and the Society for Imaging Science and Technology (IS&T) and a member of IEEE.

Experimental Session

Time: **3:30 pm – 5:00 pm, Tuesday October 22, 2013**
Location: Conference site

This is an unusual and unique session for this conference, where a small group of participants exhibits their experimental research results. These table top displays will create an opportunity to all attendees in discovering the contributions of our colleagues via first-hand observations. They will have casual Q&A opportunities during the session.

1. **Title:** Haptic displays and teleoperated robotic systems
   Nick Colonnese, **Ann Majewicz**, and **Allison Okamura**, Stanford University

2. **Title:** Cart-Pendulum stabilization using multiple time-delayed feedback
   Qingbin Gao, **Ayhan Sebastian Kammer, Umut Zalluhoglu and Nejat Olgac**, University of Connecticut

3. **Title:** Reconfigurable Omnidirectional Articulated wheeled Mobile Robot (ROAMeR)
   Javad Sovizi, **Aliakbar Alamdari**, **Xiaobo Zhou** and **Venkat N. Krovi**

4. **Title:** Demonstration of Drexel of SAS Lab's multi-robot Coherent Structure Testbed (mCoSTe)
   Matthew Michini, **Kenneth Mallory**, **Dennis Larkin**, **M. Ani Hsieh**, Drexel University
   Eric Forgoston, and **Philip A. Yecko**, Montclair State University

5. **Title:** Optimal control of plug loads for commercial building demand response
   Daniel Arnold, **Michael Sankur**, and **Dave Auslander**, University of California at Berkeley

Video Session

Time: **3:30 pm – 5:00 pm, Tuesday October 22, 2013**
Location: Conference site

As a parallel activity with the experimental session, there is a cycling video display of another set of experimental research.

Title: Responsible eigenvalue approach to consensus control of three robot system under communication delays
Wei Qiao and **Rifat Sipahi**, Northeastern University

Title: Demonstration of feedback control of smart lighting systems
Sina Afshari and **Sandipan Mishra**, Rensselaer Polytechnic Institute

Title: Bio-inspired robotic fish for animal behavior research
S. Butail, **T. Bartolini**, **V. Cianca**, **S. Macri**, and **M. Porfiri**, Polytechnic Institute of New York University

Title: MRI compatible Hemiparesis Wrist Rehabilitation Device (MHWRD)
Lauren Lacey, **Arnold Maliki**, **James Veldhorst**, **Debapriya Bhattacharjee**, and **Jun Ueda**, Georgia Tech

CONFERENCE REGISTRATION

All conference attendees must register. Personal badges will be provided to identify registered participants. On-site registration and registration packet pick-up for all advanced registrations may be done at the conference registration desk. The Registration Desk will be in operation throughout the conference.

Participants will also receive admission, breakfasts, lunches, and refreshments provided during conference coffee breaks, and the conference proceedings in CD-ROM format. Participants with full registration will receive admission to the DSCD Awards banquet. Additional DSC conference proceedings and additional tickets for the DSCC awards dinner can be purchased. Registration related guidance can be found on the conference website:

http://dsc-conference.org/DSCC/2013/

COMMITTEE MEETINGS

Information of committee meetings can be found on the conference website:
http://dsc-conference.org/DSCC/2013/

Additionally, the information will be posted at the Registration Desk.

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TECHNICAL PROGRAMS

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Keywords Index

DSCC 2013 Technical Program Monday October 21, 2013

Track T1	Track T2	Track T3	Track T4	Track T5	Track T6	Track T7
08:30-09:30 MoPK1 Paul Brest Hall Joseph Beaman "Emerging Nexus of Cyber, Modeling, and Estimation in Advanced Manufacturing"						
10:15-12:15 MoAT1 Paul Brest East Control of Advanced Combustion Engines	10:15-12:15 MoAT2 Room 123 Bipeds and Locomotion	10:15-12:15 MoAT3 Tent A Aerial Vehicles	10:15-12:15 MoAT4 Paul Brest West Wind Energy Systems and Control	10:15-12:15 MoAT5 Tent B Dynamical Modeling and Diagnostics in Biomedical Systems	10:15-12:15 MoAT6 Room 134 Control, Monitoring, and Energy Harvesting of Vibratory Systems: Active Vibration Control -1	10:15-12:15 MoAT7 Room 138 Delay Systems
12:25-13:25 MoTK1 Paul Brest Hall Stochastic Processes, Kalman Filtering and Stochastic Control						
13:30-15:30 MoBT1 Paul Brest East Control Design Methods for Advanced Powertrain Systems and Components	13:30-15:30 MoBT2 Room 123 Human Assistive Systems and Wearable Robots: Applications and Assessment	13:30-15:30 MoBT3 Tent A Aerospace Control	13:30-15:30 MoBT4 Paul Brest West Alternative Energy	13:30-15:30 MoBT5 Tent B System Identification and Therapeutic Control in Bio-Systems	13:30-15:30 MoBT6 Room 134 Control, Monitoring, and Energy Harvesting of Vibratory Systems: Active Vibration Control-2	13:30-15:30 MoBT7 Room 138 Nonlinear Control
16:00-18:00 MoCT1 Paul Brest East System Identification and Estimation for Automotive Applications	16:00-18:00 MoCT2 Room 123 Human Assistive Systems and Wearable Robots: Design and Control	16:00-18:00 MoCT3 Tent A Marine Vehicles	16:00-18:00 MoCT4 Paul Brest West Control of Building Energy Systems	16:00-18:00 MoCT5 Tent B Instrumentation and Characterization in Bio-Systems	16:00-18:00 MoCT6 Room 134 Control, Monitoring, and Energy Harvesting of Vibratory Systems: Active Vibration Control-3	16:00-18:00 MoCT7 Room 138 Nonlinear Estimation and Control

DSCC 2013 Technical Program Tuesday October 22, 2013

Track T1	Track T2	Track T3	Track T4	Track T5	Track T6	Track T7
08:30-09:30 TuNT8 Paul Brest Hall Nyquist Lecture - Galip Ulsoy "Reconfigurable Systems: The Role of Dynamics and Control"						
10:15-12:15 TuAT1 Paul Brest East Vehicle Dynamics and Control	10:15-12:15 TuAT2 Room 123 Cooperative and Networked Control	10:15-12:15 TuAT3 Tent A Nonholonomic Systems	10:15-12:15 TuAT4 Paul Brest West Estimation and Identification of Energy Systems	10:15-12:15 TuAT5 Tent B Biomedical Robots and Rehabilitation	10:15-12:15 TuAT6 Room 134 Control, Monitoring, and Energy Harvesting of Vibratory Systems: Analysis and Passive Control	10:15-12:15 TuAT7 Room 138 Optimization and Optimal Control
12:25-13:25 TuTT8 East Courtyard Modeling and Simulation: What Are the Fundamental Skills and Practices to Impart to Our Students?						
13:30-15:30 TuBT1 Paul Brest East Automotive Control Systems	13:30-15:30 TuBT2 Room 123 Haptics and Hand Motion	13:30-15:30 TuBT3 Tent A Vehicles and Human Robotics	13:30-15:30 TuBT4 Paul Brest West Battery Systems	13:30-15:30 TuBT5 Tent B Bio-Medical and Bio-Mechanical Systems	13:30-15:30 TuBT6 Room 134 Control, Monitoring, and Energy Harvesting of Vibratory Systems: Energy Harvesting	13:30-15:30 TuBT7 Room 138 Variable Structure/ Sliding-Mode Control
15:30-17:00 TuET9 East Courtyard Experimental Session				15:30-17:00 TuET10 TBD Video Session		
17:00-18:30 TuFT8 Paul Brest Hall Awards Ceremony/Oldenburger Lecture - Graham Goodwin "Beyond Servo Mechanisms: Challenges and Opportunities in Control Science"						

DSCC 2013 Technical Program Wednesday October 23, 2013

Track T1	Track T2	Track T3	Track T4	Track T5	Track T6	Track T7
08:30-09:30 WePK1 Paul Brest Hall Oussama Khatib "Robots and the Human"						
10:15-12:15 WeAT1 Paul Brest East Intelligent Transportation Systems	10:15-12:15 WeAT2 Room 123 Robotic Manipulators	10:15-12:15 WeAT3 Tent A Piezoelectric Actuation and Nanoscale Control	10:15-12:15 WeAT4 Paul Brest West Flow and Thermal Systems	10:15-12:15 WeAT5 Tent B Biologically-Inspired Control and Its Applications	10:15-12:15 WeAT6 Room 134 Beams and Flexible Structures	10:15-12:15 WeAT7 Room 138 Linear Systems and Robust Control
12:25-13:25 WeTK1 Paul Brest Hall Updates and New Opportunities for Dynamic Systems and Control at the National Science Foundation (NSF)						
13:30-15:30 WeBT1 Paul Brest East Vehicle Path Planning and Collision Avoidance	13:30-15:30 WeBT2 Room 123 Robotics and Manipulators	13:30-15:30 WeBT3 Tent A Sensing	13:30-15:30 WeBT4 Paul Brest West Control of Mechanical Systems	13:30-15:30 WeBT5 Tent B System Identification and Modeling	13:30-15:30 WeBT6 Room 134 Vibrational and Mechanical Systems	13:30-15:30 WeBT7 Room 138 Fault Detection

Detailed Program Listing

Content List of 6th Annual Dynamic Systems and Control Conference

Technical Program for Monday October 21, 2013

98-107.

Mebarki, Rafik	PRISMA Lab. Univ. degli Studi di Napoli Federico II
Lippiello, Vincenzo	Univ. of Naples Federico II
Siciliano, Bruno	Univ. degli Studi di Napoli Federico II

10:35-10:55 MoAT3.2

Identification of Instabilities in Rotorcraft Systems, pp. 108-112.

Sonti, Siddharth	Pennsylvania State Univ. Univ. Park, PA
Eric, Keller	Pennsylvania State Univ. Univ. Park, PA
Horn, Joseph	The Pennsylvania State Univ.
Ray, Asok	Pennsylvania State Univ.

10:55-11:15 MoAT3.3

Dynamic Modeling and Simulation of a Remote-Controlled Helicopter with a Suspended Load, pp. 113-118.

Potter, James Jackson	Georgia Inst. of Tech.
Simpson, Ryan	Georgia Inst. of Tech.
Singhose, William	Georgia Inst. of Tech.

11:15-11:35 MoAT3.4

Enhanced Proportional-Derivative Control of a Micro Quadcopter, pp. 119-123.

Johnson, Norman L.	Univ. of Nevada, Reno
Leang, Kam K.	Univ. of Nevada, Reno

11:35-11:55 MoAT3.5

Proportional Navigation (pn) Based Tracking of Ground Targets by Quadrotor Uavs, pp. 124-133.

Tan, Ruoyu	Univ. of Cincinnati
Kumar, Manish	Univ. of Toledo

11:55-12:15 MoAT3.6

*A Van Der Pol Oscillator Model for Lift Force Produced by Heaving NACA-0012 Airfoil at Low Reynolds Number**.

Khalid, Muhammad Saif Ullah	National Univ. of Sciences & Tech.
Akhtar, Imran	National Univ. of Sciences & Tech.

MoAT4 Paul Brest West

Wind Energy Systems and Control (Invited session)

Chair: Vermillion, Christopher	Altaeros Energies
Co-Chair: Chen, Dongmei	The Univ. of Texas at Austin
Organizer: Vermillion, Christopher	Altaeros Energies
Organizer: Chen, Dongmei	The Univ. of Texas at Austin

10:15-10:35 MoAT4.1

Altitude and Crosswind Motion Control for Optimal Power-Point Tracking in Tethered Wind Energy Systems with Airborne Power Generation (I), pp. 134-142.

Vermillion, Christopher	Altaeros Energies

10:35-10:55 MoAT4.2

Optimal Control of a Wind Turbine for Tradeoff Analysis between Energy Harvesting and Noise Emission (I), pp. 143-147.

Shaltout, Mohamed	Univ. of Texas at Austin
Chen, Dongmei	The Univ. of Texas at Austin

10:55-11:15 MoAT4.3

An Application of the Autogyro Theory to Airborne Wind Energy Extraction (I), pp. 148-155.

Rimkus, Sigitas	Univ. of Central Florida
Das, Tuhin	Univ. of Central Florida

11:15-11:35 MoAT4.4

Active Control of Wind Turbine Rotor Torsional Vibration (I), pp. 156-163.

White, Warren N.	Kansas State Univ.
Yu, Zhichao	Kansas State Univ.
Miller, Ruth Douglas	Kansas StateUniversity
Ochs, David	Kansas State Univ.

11:35-11:55 MoAT4.5

Maximizing Wind Farm Energy Capture Via Nested-Loop Extremum Seeking Control (I), pp. 164-171.

Yang, Zhongzhou	Univ. of Wisconsin-Milwaukee
Li, Yaoyu	Univ. of Texas at Dallas
Seem, John E.	Johnson Controls Inc.

11:55-12:15 MoAT4.6

Nonlinear Controller Design with Bandwidth Consideration for a Novel Compressed Air Energy Storage System (I), pp. 172-179.

Saadat, Mohsen	Univ. of Minnesota
Shirazi, Farzad	Univ. of Minnesota- Postdoctoral Res. Associate
Li, Perry Y.	Univ. of Minnesota

MoAT5 Tent B

Dynamical Modeling and Diagnostics in Biomedical Systems (Invited session)

Chair: Ghorbanian, Parham	Villanova Univ.
Co-Chair: Jalali, Ali	Villanova Univ.
Organizer: Ghorbanian, Parham	Villanova Univ.
Organizer: Jalali, Ali	Villanova Univ.
Organizer: Nataraj, C.	Villanova Univ.
Organizer: Ashrafiuon, Hashem	Villanova Univ.

10:15-10:35 MoAT5.1

State Dynamics of the Epileptic Brain (I), pp. 180-186.

Burns, Samnuel	Johns Hopkins Univ.
Santaniello, Sabato	Johns Hopkins Univ.
Anderson, William	Johns Hopkins Hospital
Sarma, Sridevi V.	Johns Hopkins Univ.

10:35-10:55 MoAT5.2

Modeling and System Identification of Hemodynamic Responses to Vasopressor-Inotropes (I), pp. 187-195.

Bighamian, Ramin	Univ. of Maryland
Soleymani, Sadaf	Univ. of Southern California
Reisner, Andrew	Harvard Medical School
Seri, Istvan	Children's Hospital Los Angeles
Hahn, Jin-Oh	Univ. of Maryland

10:55-11:15 MoAT5.3

Stochastic Dynamic Modeling of the Human Brain EEG Signal (I), pp. 196-201.

Ghorbanian, Parham	Villanova Univ.
Ramakrishnan, Subramanian	Villanova Univ.
Simon, Adam	Cerora, Inc.
Ashrafiuon, Hashem	Villanova Univ.

11:15-11:35 MoAT5.4

Classification of Postural Response in Parkinson's Patients Using

Support Vector Machines (I), pp. 202-209.

Shukla, Amit	Miami Univ.
Mani, Ashutosh	Univ. of Cincinnati
Bhattacharya, Amit	Univ. of Cincinnati
Revilla, Fredy	Univ. of Cincinnati

11:35-11:55 MoAT5.5

Theoretical Development and Experimental Validation of an Adaptive Controller for Tremor Suppression at Musculoskeletal Level, pp. 210-217.

Taheri, Behzad	Southern Methodist Univ.
Case, David	Southern Methodist Univ.
Richer, Edmond	Southern Methodist Univ.

11:55-12:15 MoAT5.6

A Method of Swing Leg Control for a Minimally Actuated Medical Exoskeleton for Individuals with Paralysis, pp. 218-226.

Reid, Jason I.	Univ. of California, Berkeley
McKinley, Michael G.	Univ. of California
Tung, Wayne Yi-Wei	Univ. of California, Berkeley
Pillai, Minerva Vasudevan	Univ. of California, Berkeley
Kazerooni, Homayoon	Univ. of California at Berkeley

MoAT6 Room 134

Control, Monitoring, and Energy Harvesting of Vibratory Systems: Active Vibration Control -1 (Invited session)

Chair: Zuo, Lei	Stony Brook Univ. - SUNY
Co-Chair: Kajiwara, Itsuro	Hokkaido Univ.
Organizer: Zuo, Lei	Stony Brook Univ. - SUNY
Organizer: Tang, Jiong	Univ. of Connecticut
Organizer: Sipahi, Rifat	Northeastern Univ.
Organizer: Caruntu, Dumitru	Univ. of Texas Pan American
Organizer: Nishimura, Hidekazu	Keio Univ.
Organizer: Kajiwara, Itsuro	Hokkaido Univ.

10:15-10:35 MoAT6.1

Bridge Life Extension Using Semi-Active Vibration Control (I), pp. 227-235.

Nelson, Garrett	Univ. of Minnesota
Rajamani, Rajesh	Univ. of Minnesota
Gastineau, Andrew	Univ. of Minnesota
Schultz, Arturo	Univ. of Minnesota
Wojtkiewicz, Steve	Univ. of Minnesota

10:35-10:55 MoAT6.2

Development of Nonlinear Control Algorithms for Shaking Table Tests (I), pp. 236-243.

Yang, T.Y.	Univ. of British Columbia
Li, Kang	National Taiwan Univ.
Lin, Jian Yuan	National Taiwan Univ.
Li, Yuanjie	Univ. of British Columbia

10:55-11:15 MoAT6.3

Regenerative Vibration Control of Tall Buildings Using Model Predictive Control (I), pp. 244-253.

Liu, Yilun	State Univ. of New York at Stony Brook
Zuo, Lei	Stony Brook Univ. - SUNY
Tang, Xiudong	Stony Brook Univ.

11:15-11:35 MoAT6.4

Active Vibration Control Based on Self-Sensing for Unkown Target Structures by Direct Velocity Feedback with Adaptive Feed-Forward Cancellation (I), pp. 254-258.

Yabui,, Shota	Hokkaido Univ.
Kajiwara, Itsuro	Hokkaido Univ.
Ookita, Ryohei	Hokkaido Univ. Div. of Human Mechanical\\ Systems and

11:35-11:55 MoAT6.5

Closed Loop Fusion Technique for the Shaking Table Motion Control (I), pp. 259-264.

Shimono, Keisuke	Tokyo Univ. of Agriculture and Tech.
Tagawa, Yasutaka	Tokyo Univ. of Agriculture and Tech.

11:55-12:15 MoAT6.6

Simulation Based Control and Its Application to a Crane System (I), pp. 265-274.

Tagawa, Yasutaka	Tokyo Univ. of Agriculture and Tech.
Shimono, Keisuke	Tokyo Univ. of Agriculture and Tech.

MoAT7 Room 138

Delay Systems (Contributed session)

Chair: Sipahi, Rifat	Northeastern Univ.
Co-Chair: Ersal, Tulga	Univ. of Michigan

10:15-10:35 MoAT7.1

Graph Laplacian Design for Fast Consensus of a {LTI} System with Heterogeneous Agent Couplings and Homogeneous Inter-Agent Delays, pp. 275-282.

Qiao, Wei	Northeastern Univ.
Atay, Fatihcan	Max Planck Inst. for Mathematics in the Sciences
Sipahi, Rifat	Northeastern Univ.

10:35-10:55 MoAT7.2

Equivalency of Stability Transitions between the Sds (spectral Delay Space) and Ds (delay Space), pp. 283-291.

Gao, Qingbin	Univ. of Connnecticut
Zalluhoglu, Umut	Univ. of Connecticut
Olgac, Nejat	Univ. of Connecticut

10:55-11:15 MoAT7.3

A Comparison of the Simulated Dynamics of Various Models Used to Predict Undeformed Chip Thickness in High-Speed Low-Radial-Immersion Milling Processes, pp. 292-298.

Bryan, Josiah	Univ. of Missouri
Fales, Roger	Univ. of Missouri-Columbia

11:15-11:35 MoAT7.4

Design and Stability Analysis of Delayed Resonator with Acceleration Feedback, pp. 299-308.

Vyhlidal, Tomas	Faculty of Mechanical Engineering, Czech Tech. Univ. in
Olgac, Nejat	Univ. of Connecticut
Kucera, Vladimir	Faculty of Mechanical Engineering, Czech Tech. Univ. in

11:35-11:55 MoAT7.5

An Observer Based Framework to Improve Fidelity in Internet-Distributed Hardware-In-The-Loop Simulations, pp. 309-317.

Tandon, Akshar	Univ. of Michigan

Brudnak, Mark	The US Army Tank-Automotive Res. Development andEngineering
Stein, Jeffrey L.	Univ. of Michigan
Ersal, Tulga	Univ. of Michigan

11:55-12:15 MoAT7.6

Preserving Stability under Communication Delays in Multi Agent Systems, pp. 318-327.

Rastgoftar, Hossein	Univ. of Central Florida
Jayasuriya, Suhada	Univ. of Central Florida

MoBT1 Paul Brest East

Control Design Methods for Advanced Powertrain Systems and Components (Invited session)

Chair: Shahbakhti, Mahdi	Michigan Tech. Univ.
Co-Chair: Shaver, Gregory M.	Purdue Univ.
Organizer: Canova, Marcello	The Ohio State Univ.
Organizer: Scacchioli, Annalisa	New York Univ.
Organizer: Yan, Fengjun	McMaster Univ.
Organizer: Hall, Carrie	Purdue Univ.
Organizer: Kolodziej, Jason	Rochester Inst. of Tech.
Organizer: Shahbakhti, Mahdi	Michigan Tech. Univ.

13:30-13:50 MoBT1.1

Control Design for Cancellation of Unnatural Reaction Torque and Vibrations in Variable-Gear-Ratio Steering System (I), pp. 328-337.

Oshima, Atsushi	NSK Ltd
Chen, Xu	Univ. of California, Berkeley
Sugita, Sumio	NSK Ltd
Tomizuka, Masayoshi	Univ. of California, Berkeley

13:50-14:10 MoBT1.2

Torque Phase Shift Control Based on Clutch Torque Estimation (I), pp. 338-345.

Yanakiev, Diana	Ford Motor Company
Fujii, Yuji	Ford Motor Company
Tseng, Eric	Ford Motor Company
Pietron, Gregory M.	Ford Motor Co
Kucharski, Joseph F.	Ford Motor Co.
Kapas, Nimrod	Ford Motor Co

14:10-14:30 MoBT1.3

Investigation on the Energy Management Strategy for Hydraulic Hybrid Wheel Loaders (I), pp. 346-355.

Wang, Feng	Univ. of Minnesota
Mohd Zulkefli, Mohd Azrin	Univ. of Minnesota
Sun, Zongxuan	Univ. of Minnesota
Stelson, Kim A.	Univ. of Minnesota

14:30-14:50 MoBT1.4

Design, Modeling and Control of a Novel Architecture for Automatic Transmissions (I), pp. 356-364.

Mallela, Virinchi	Univ. of Minnesota - Twin Cities
Sun, Zongxuan	Univ. of Minnesota

14:50-15:10 MoBT1.5

Observer Based Oxygen Fraction Estimation for a Dual-Loop EGR Diesel Engine Fueled with Biodiesel Blends (I), pp. 365-371.

Zhao, Junfeng	The Ohio State Univ.
Wang, Junmin	The Ohio State Univ.

15:10-15:30 MoBT1.6

A Dual-Loop EGR Engine Air-Path Oxygen Concentration Model with Time-Varying Transport Delays (I), pp. 372-378.

Zeng, Xiangrui	The Ohio State Univ.
Wang, Junmin	The Ohio State Univ.

MoBT2 Room 123

Human Assistive Systems and Wearable Robots: Applications and Assessment (Invited session)

Chair: Ueda, Jun	Georgia Inst. of Tech.
Co-Chair: Deshpande, Ashish	Univ. of Texas
Organizer: Ueda, Jun	Georgia Inst. of Tech.
Organizer: Deshpande, Ashish	Univ. of Texas

13:30-13:50 MoBT2.1

Body-Segment Orientation Estimation in Rider-Bicycle Interactions with an Un-Calibrated Monocular Camera and Wearable Gyroscopes (I), pp. 379-388.

Lu, Xiang	Rutgers Univ.
Zhang, Yizhai	Rutgers Univ.
Yu, Kaiyan	Rutgers Univ.
Yi, Jingang	Rutgers Univ.
Liu, Jingtai	Nankai Univ.

13:50-14:10 MoBT2.2

Interaction Control of a Non-Backdriveable MR-Compatible Actuator through Series Elasticity (I), pp. 389-398.

Sergi, Fabrizio	Rice Univ.
Chawda, Vinay	Rice Univ.
O'Malley, Marcia	Rice Univ.

14:10-14:30 MoBT2.3

Kinematic Analysis of Virtual Reality Task Intensity Induced by a Rehabilitation Robotic System in Stroke Patients (I), pp. 399-406.

Simkins, Matt	UC Santa Cruz
Roldan, Jay Ryan	Univ. of California Santa Cruz
Kim, Hyunchul	Apple Inc
Abrams, Gary	Univ. of California, San Francisco
Byl, Nancy	Univ. of California San Francisco
Rosen, Jacob	Univ. of California - Santa Cruz

14:30-14:50 MoBT2.4

Control of Voluntary and Involuntary Nerve Impulses for Hemiparesis Rehabilitation and MRI Study (I), pp. 407-414.

Lacey, Lauren	Georgia Inst. of Tech.
Buharin, Vasiliy	Georgia Inst. of Tech.
Turkseven, Melih	Georgia Inst. of Tech.
Shinohara, Minoru	Georgia Inst. of Tech.
Ueda, Jun	Georgia Inst. of Tech.

14:50-15:10 MoBT2.5

Interaction Control for Rehabilitation Robotics Via a Low-Cost Force Sensing Handle (I), pp. 415-419.

Erwin, Andrew	Rice Univ.
Sergi, Fabrizio	Rice Univ.
Chawda, Vinay	Rice Univ.
O'Malley, Marcia	Rice Univ.

15:10-15:30 MoBT2.6

Control and Coordination of Supernumerary Robotic Limbs Based on Human Motion Detection and Task Petri Net Model (I), pp. 420-426.

Llorens-Bonilla, Baldin	Massachusetts Inst. of Tech.

Asada, H. Harry — Massachusetts Inst. of Tech.

MoBT3 — Tent A
Aerospace Control (Contributed session)

Chair: Sun, Jing — Univ. of Michigan
Co-Chair: Leang, Kam K. — Univ. of Nevada, Reno

13:30-13:50 — MoBT3.1

Model Predictive Control of Spacecraft Relative Motion Maneuvers Using the IPA-SQP Approach, pp. 427-435.

Park, Hyeongjun — Univ. of Michigan
Kolmanovsky, Ilya — The Univ. of Michigan, Ann Arbor
Sun, Jing — Univ. of Michigan

13:50-14:10 — MoBT3.2

Adaptive Control with Convex Saturation Constraints, pp. 436-445.

Yan, Jin — Univ. of Michigan
Santos, Davi Antônio — Inst. Tecnológico de Aeronáutica
Bernstein, Dennis S. — Univ. of Michigan

14:10-14:30 — MoBT3.3

Geometric Mechanics Based Modeling of the Attitude Dynamics and Control of Spacecraft with Variable Speed Control Moment Gyroscopes, pp. 446-455.

Viswanathan, Sasi Prabhakaran — New Mexico State Univ.
Sanyal, Amit — New Mexico State Univ.
Leve, Frederick — Air Force Res. Lab. Space Vehicles Directorate
McClamroch, N. Harris — Univ. of Michigan

14:30-14:50 — MoBT3.4

QUATERNION BASED MODEL FOR 6-DoF VEHICLES WITH APPLICATION TO a LOW EARTH ORBITER (I), pp. 456-462.

Cepeda-Gomez, Rudy — Univ. Santo Tomas

14:50-15:10 — MoBT3.5

A Nonlinear Observer Design for a Rigid Body in the Proximity of a Spherical Asteroid, pp. 463-469.

Izadi, Maziar — New Mexico State Univ.
Bohn, Jan — New Mexico State Univ.
Lee, Daero — New Mexico State Univ.
Sanyal, Amit — New Mexico State Univ.
Butcher, Eric — New Mexico State Univ.
Scheeres, Daniel — The Univ. of Colorado

15:10-15:30 — MoBT3.6

Applications of Slider Chain Inversion in Control Actuation Systems, pp. 470-476.

Hasturk, Ozgur — Roketsan Missile Industries Inc.

MoBT4 — Paul Brest West
Alternative Energy (Contributed session)

Chair: Madani, Omid — Univ. of Central Florida
Co-Chair: Li, Yaoyu — Univ. of Texas at Dallas

13:30-13:50 — MoBT4.1

Transient Control in Multivariable Systems: A Study Motivated by Fuel Cells, pp. 477-485.

Madani, Omid — Univ. of Central Florida
Das, Tuhin — Univ. of Central Florida

13:50-14:10 — MoBT4.2

Enhancing Energy Harvesting System Using Materials with Fractional Order Stiffness, pp. 486-490.

Kwuimy, Cedrick — VILLANOVA Univ. Mech Eng
Nataraj, 'Nat' C. — Villanova Univ.
Litak, Grzegorz — Department of Applied Mechanics, Lublin Univ. of Tech.

14:10-14:30 — MoBT4.3

Maximum Power Point Tracking of Multi-String Photovoltaic Array Via Simultaneous Perturbation Stochastic Approximation, pp. 491-498.

Xiao, Yan — The Univ. of Texas at Dallas
Li, Yaoyu — Univ. of Texas at Dallas
Seem, John E. — Johnson Controls Inc.
Rajashekara, Kaushik — Univ. of Texas at Dallas

14:30-14:50 — MoBT4.4

System Level Dynamic Modeling Framework Being Developed at Clemson University's Wind Turbine Drivetrain Testing Facility, pp. 499-508.

Schkoda, Ryan — Clemson Univ.
Bulgakov, Konstantin — Clemson Univ.
Addepalli, Kalyan Chakravarthy — Clemson Univ.
Haque, Imtiaz — Clemson Univ.

14:50-15:10 — MoBT4.5

Modeling and Respose Analysis of Piezoelectric Flag in Wind Flow, pp. 509-516.

Wynn, Logan — The Univ. of Alabama
Truitt, Andrew — The Univ. of Alabama
Heim, Isaac — Univ. of Alabama
Mahmoodi, Nima — The Univ. of Alabama

15:10-15:30 — MoBT4.6

*FUZZY ADAPTIVE OUTPUT FEEDBACK CONTROL STRATEGY for STANDALONE WIND ENERGY CONVERSION SYSTEMS**.

Nguyen, Hoa — Idaho State Univ.
Naidu, D. Subbaram — Idaho State Univ.

MoBT5 — Tent B
System Identification and Therapeutic Control in Bio-Systems (Invited session)

Chair: Hahn, Jin-Oh — Univ. of Maryland
Co-Chair: Fazeli, Nima — Univ. of Maryland Coll. Park
Organizer: Hahn, Jin-Oh — Univ. of Maryland
Organizer: Asada, H. Harry — Massachusetts Inst. of Tech.

13:30-13:50 — MoBT5.1

Prediction of Icu In-Hospital Mortality Using Artificial Neural Networks (I), pp. 517-525.

Xia, Henian — Univ. of Tennessee
Keeney, Nathan — Univ. of Tennessee
Daley, Brian — Univ. of Tennessee Medical Center
Petrie, Adam — Univ. of Tennessee
Zhao, Xiaopeng — Univ. of Tennessee

13:50-14:10 — MoBT5.2

Integrated Mechanistic-Empirical Modeling of Cellular Response Based on Intracellular Signaling Dynamics (I), pp. 526-530.

Mayalu, Michaelle — Massachusetts Inst. of Tech.
Asada, H. Harry — Massachusetts Inst. of Tech.

14:10-14:30 — MoBT5.3

Modeling and System Identification of Arterial Hemodynamics in Humans (I), pp. 531-538.

Rashedi, Mohammad	Univ. of Alberta
Fazeli, Nima	Univ. of Maryland Coll. Park
Alyssa, Chappell	Univ. of Alberta
Wang, Shaohua	Univ. of Alberta
MacArthur, Roderick	Univ. of Alberta
McMurtry, M. Sean	Univ. of Alberta
Finegan, Barry	Univ. of Alberta
Hahn, Jin-Oh	Univ. of Maryland

14:30-14:50 MoBT5.4

Active Non-Intrusive System Identification for Cardiovascular Monitoring Part Ii: Development of System Identifiction Algorithm (I), pp. 539-548.

Fazeli, Nima	Univ. of Maryland Coll. Park
Hahn, Jin-Oh	Univ. of Maryland

14:50-15:10 MoBT5.5

Improving Cardiopulmonary Resuscitation (CPR) by Dynamic Variation of CPR Parameters (I), pp. 549-554.

Jalali, Ali	Villanova Univ.
Berg, Robert A.	Children's Hospital of Philadelphia
Nadkarni, Vinay M.	Children's Hospital of Philadelphia
Nataraj, 'Nat' C.	Villanova Univ.

15:10-15:30 MoBT5.6

Ankle Mechanical Impedance under Muscle Fatigue (I), pp. 555-559.

Wang, Shuo	Massachusetts Inst. of Tech.
Lee, Hyunglae	Mass. Inst. of Tech.
Hogan, Neville	Massachusetts Inst. of Tech.

MoBT6 Room 134

Control, Monitoring, and Energy Harvesting of Vibratory Systems: Active Vibration Control-2 (Invited session)

Chair: Sipahi, Rifat	Northeastern Univ.
Co-Chair: Caruntu, Dumitru	Univ. of Texas Pan American
Organizer: Zuo, Lei	Stony Brook Univ. - SUNY
Organizer: Tang, Jiong	Univ. of Connecticut
Organizer: Sipahi, Rifat	Northeastern Univ.
Organizer: Caruntu, Dumitru	Univ. of Texas Pan American
Organizer: Nishimura, Hidekazu	Keio Univ.
Organizer: Kajiwara, Itsuro	Hokkaido Univ.

13:30-13:50 MoBT6.1

Acceleration Control of Powered Wheelchairs with Nil-Mode-Exciting Profiler Considering Vibration Characteristic of Human Body (I), pp. 560-567.

Takahashi, Masaki	Keio Univ.
Okugawa, Kyohei	Keio Univ.

13:50-14:10 MoBT6.2

A Trajectory Shaping Approach for Suppressing the Fundamental Vibratory Mode in Strain Wave Gearing Mechanisms (I), pp. 568-576.

Chan, Michael	Univ. of California, Berkeley
Tomizuka, Masayoshi	Univ. of California, Berkeley

14:10-14:30 MoBT6.3

Semi-Active Control Methodology for Control of Air Spring-Valve-Accumulator System (I), pp. 577-586.

Robinson, William Daniel	John Deere
Kelkar, Atul	Iowa State Univ.
Vogel, Jerald	IVS, Inc

14:30-14:50 MoBT6.4

Control of a Nonlinear Pressure-Regulating Engine Bleed Valve in Aircraft Air Management Systems (I), pp. 587-592.

Cooper, John	Univ. of Connecticut
Cao, Chengyu	Univ. of Connecticut
Tang, Jiong	Univ. of Connecticut

14:50-15:10 MoBT6.5

Modal Analysis of a Motorcycle Motion During Braking for Its Stabilization Control System Design (I), pp. 593-600.

Murakami, Shintaroh	Keio Univ.
Nishimura, Hidekazu	Keio Univ.

15:10-15:30 MoBT6.6

Vehicle Stability Control in Anti-Lock Braking System on Split-U Road Surface Considering Driver in the Loop (I), pp. 601-608.

Yu, Liangyao	Tsinghua Univ.
You, Changxi	Tsinghua Univ.
Song, Jian	Tsinghua Univ.

MoBT7 Room 138

Nonlinear Control (Contributed session)

Chair: Messner, William	Tufts Univ.
Co-Chair: Ren, Beibei	Texas Tech. Univ.

13:30-13:50 MoBT7.1

UDE-Based Robust Control for a Class of Non-Affine Nonlinear Systems, pp. 609-614.

Ren, Beibei	Texas Tech. Univ.
Zhong, Qing-Chang	The Univ. of Sheffield

13:50-14:10 MoBT7.2

Invariance Control of a Class of Cascade Nonlinear Systems with Input Unmodeled Dynamics, pp. 615-622.

Wu, Caiyun	State Key Lab. of Synthetical Automation for Process Indus
Dimirovski, Georgi Marko	Dogus Univ. of Istanbul
Zhao, Jun	Northeastern Univ.
Ma, Ruicheng	Liaoning Univ.

14:10-14:30 MoBT7.3

Nonlinear Compensation for High Performance Feedback Systems with Actuator Imperfections, pp. 623-631.

Mock, Cameron	Univ. of Wyoming
Hamilton, Zachary	Univ. of Wyoming
Carruthers, Dustin	Left Hand Design Corp.
OBrien, John F.	Univ. of Wyoming

14:30-14:50 MoBT7.4

Proportional Nonlinear Systems: A Liable Class for Global Exponential State-Feedback Stabilization, pp. 632-639.

Carravetta, Francesco	IASI-CNR

14:50-15:10 MoBT7.5

Nonlinear Control of an Unmanned Amphibious Vehicle, pp. 640-644.

Alvarez, Jose	Florida Atlantic Univ.
Bertaska, Ivan Rodrigues	Florida Atlantic Univ.
von Ellenrieder, Karl	Florida Atlantic Univ.

15:10-15:30 MoBT7.6

Controller Design for Nonlinear Multi-Input/Multi-Output Systems Using the Contoured Robust Controller Bode Plot, pp. 645-653.

Taylor, Jd	Carnegie Mellon Univ.

Messner, William	Tufts Univ.

MoCT1	Paul Brest East
System Identification and Estimation for Automotive Applications (Invited session)	
Chair: Canova, Marcello	The Ohio State Univ.
Co-Chair: Hall, Carrie	Purdue Univ.
Organizer: Yan, Fengjun	McMaster Univ.
Organizer: Shahbakhti, Mahdi	Michigan Tech. Univ.
Organizer: Canova, Marcello	The Ohio State Univ.
Organizer: Hall, Carrie	Purdue Univ.
Organizer: Kolodziej, Jason	Rochester Inst. of Tech.
Organizer: Scacchioli, Annalisa	New York Univ.

16:00-16:20	MoCT1.1
Robust Sideslip Angle Estimation for Lightweight Vehicles Using Smooth Variable Structure Filter (I), pp. 654-661.	
Huang, Xiaoyu	The Ohio State Univ.
Wang, Junmin	The Ohio State Univ.

16:20-16:40	MoCT1.2
Real-Time Battery Model Identification Using a Two Time-Scaled Approach (I), pp. 662-668.	
Hu, Yiran	General Motors R/D
Wang, Yue-Yun	General Motors Company

16:40-17:00	MoCT1.3
Robust Sideslip Angle Estimation for Over-Actuated Electric Vehicles: A Linear Parameter Varying System Approach (I), pp. 669-677.	
Chen, Yan	Ohio State Univ.
Wang, Junmin	The Ohio State Univ.

17:00-17:20	MoCT1.4
Vehicle Health Inferencing Using Feature-Based Neural-Symbolic Networks (I), pp. 678-682.	
Aasted, Christopher	Harvard Medical School / Boston Children's Hospital
Lim, Sun-Wook	New York Inst. of Tech.
Shoureshi, Rahmat	New York Inst. of Tech.

17:20-17:40	MoCT1.5
Online Adaptive Residual Mass Estimation in a Multicylinder Recompression HCCI Engine (I), pp. 683-691.	
Larimore, Jacob	Univ. of Michigan
Jade, Shyam	Univ. of Michigan
Hellström, Erik	Univ. of Michigan
Vanier, Julien	Robert Bosch LLC.
Jiang, Li	Robert Bosch LLC
Stefanopoulou, Anna G.	Univ. of Michigan

17:40-18:00	MoCT1.6
Cycle-By-Cycle Based In-Cylinder Temperature Estimation for Diesel Engines (I), pp. 692-699.	
Chen, Song	McMaster Univ.
Yan, Fengjun	McMaster Univ.

MoCT2	Room 123
Human Assistive Systems and Wearable Robots: Design and Control (Invited session)	
Chair: Ueda, Jun	Georgia Inst. of Tech.
Co-Chair: Deshpande, Ashish	Univ. of Texas
Organizer: Ueda, Jun	Georgia Inst. of Tech.
Organizer: Deshpande, Ashish	Univ. of Texas

16:00-16:20	MoCT2.1
Kinematics and Dynamics of a Biologically Inspired Index Finger Exoskeleton (I), pp. 700-709.	
Agarwal, Priyanshu	The Univ. of Texas at Austin
Hechanova, Arnold	The Univ. of Texas at Austin
Deshpande, Ashish	Univ. of Texas

16:20-16:40	MoCT2.2
Nonlinear Passive Elements Using Cam-Based Springs for Powered Robotic Ankles (I), pp. 710-718.	
Realmuto, Jonathan	U. of Washington
Klute, Glenn	VA Puget Sound Health Care System
Devasia, Santosh	Univ. of Washington

16:40-17:00	MoCT2.3
Novel Design of a Passive Variable Stiffness Joint Mechanism: Inspiration from Biomechanics of Hand Joints (I), pp. 719-726.	
Kuo, Pei-Hsin	Univ. of Texas
Deshpande, Ashish	Univ. of Texas

17:00-17:20	MoCT2.4
Design of a Minimally Actuated Medical Exoskeleton with Mechanical Swing-Phase Gait Generation and Sit-Stand Assistance (I), pp. 727-735.	
Tung, Wayne Yi-Wei	Univ. of California, Berkeley
McKinley, Michael G.	Univ. of California
Kazerooni, Homayoon	Univ. of California at Berkeley
Pillai, Minerva Vasudevan	Univ. of California, Berkeley
Reid, Jason I.	Univ. of California, Berkeley

17:20-17:40	MoCT2.5
Comparison of Ultrasound Muscle Stiffness Measurement and Electromyography towards Validation of an Algorithm for Individual Muscle Control (I), pp. 736-745.	
Brown, Ellenor	Georgia Inst. of Tech.
Aomoto, Kazuya	Nara Inst. of Science and Tech.
Ikeda, Atsutoshi	Nara Inst. of Science and Tech.
Ogasawara, Tsukasa	Nara Inst. of science and Tech.
Yoshitake, Yasuhide	National Inst. of Fitness and Sports
Shinohara, Minoru	Georgia Inst. of Tech.
Ueda, Jun	Georgia Inst. of Tech.

17:40-18:00	MoCT2.6
Control of Autonomous Robots Using the Principles of Neuromodulation (I), pp. 746-753.	
Samanta, Biswanath	Georgia Southern Univ.
Prince, Islam	Georgia Southern Univ.

MoCT3	Tent A
Marine Vehicles (Contributed session)	
Chair: Kiriakidis, Kiriakos	U.S. Naval Acad.
Co-Chair: Zhang, Feitian	Michigan State Univ.

16:00-16:20	MoCT3.1
Backstepping-Based Hybrid Target Tracking Control for a Carangiform Robotic Fish, pp. 754-762.	
Chen, Songlin	Harbin Inst. of Tech.
Wang, Jianxun	Michigan State Univ.
Tan, Xiaobo	Michigan State Univ.

16:20-16:40	MoCT3.2
Gliding Robotic Fish and Its Tail-Enabled Yaw Motion Stabilization Using Sliding Mode Control, pp. 763-772.	
Zhang, Feitian	Michigan State Univ.
Tan, Xiaobo	Michigan State Univ.

16:40-17:00	MoCT3.3
Adaptive Optimal Power Trade-Off in Underwater Sensor Networks, pp. 773-782.	
Jha, Devesh	Pennsylvania State Univ. Univ. Park, PA
Wettergren, Thomas A.	Naval Undersea Warfare Center
Ray, Asok	Pennsylvania State Univ.

17:00-17:20	MoCT3.4
Planning the Minimum Time Course for Autonomous Underwater Vehicle in Uncertain Current, pp. 783-786.	
Hurni, Michael	US Naval Acad.
Kiriakidis, Kiriakos	U.S. Naval Acad.
Nicholson, John	US Naval Acad.

17:20-17:40	MoCT3.5
An Experimental Testbed for Multi-Robot Tracking of Manifolds and Coherent Structures in Flows, pp. 787-796.	
Michini, Matthew	Drexel Univ.
Mallory, Kenneth	Drexel Univ.
Larkin, Dennis	Drexel Univ.
Hsieh, M. Ani	Drexel Univ.
Forgoston, Eric	Montclair State Univ.
Yecko, Philip A.	Montclair State Univ.

17:40-18:00	MoCT3.6
Experimental Evaluation of Approach Behavior for Autonomous Surface Vehicles, pp. 797-805.	
Bertaska, Ivan Rodrigues	Florida Atlantic Univ.
Alvarez, Jose	Florida Atlantic Univ.
Sinisterra, Armando Jose	Florida Atlantic Univ.
von Ellenrieder, Karl	Florida Atlantic Univ.
Dhanak, Manhar	Florida Atlantic Univ.
Shah, Brual	Univ. of Maryland
Svec, Petr	Univ. of Maryland, Coll. Park
Gupta, Satyandra	Univ. of Maryland

MoCT4	Paul Brest West
Control of Building Energy Systems (Invited session)	
Chair: Rasmussen, Bryan	Texas A&M Univ.
Co-Chair: Chen, Dongmei	The Univ. of Texas at Austin
Organizer: Rasmussen, Bryan	Texas A&M Univ.
Organizer: Chen, Dongmei	The Univ. of Texas at Austin

16:00-16:20	MoCT4.1
Optimal Control of Office Plug-Loads for Commercial Building Demand Response (I), pp. 806-813.	
Arnold, Daniel	Univ. of California Berkeley
Sankur, Michael	Univ. of California, Berkeley
Auslander, David	Univ. of California Berkeley

16:20-16:40	MoCT4.2
Dynamic Energy Management of a Residential Energy Eco-System (I), pp. 814-823.	
Muratori, Matteo	The Ohio State Univ.
Chang, Chin-Yao	The Ohio State Univ.
Rizzoni, Giorgio	Ohio State Univ.
Zhang, Wei	The Ohio State Univ.

16:40-17:00	MoCT4.3
A Model-Based Predictive Control Approach for a Building Cooling System with Ice Storage (I), pp. 824-832.	
Raissi Dehkordi, Vahid	Natural Res. Canada
Candanedo, José	Natural Res. Canada

17:00-17:20	MoCT4.4
Pareto Optimal Setpoints for HVAC Networks Via Iterative Nearest Neighbor Communication (I), pp. 833-842.	
Elliott, Matthew	Texas A&M Univ.
Bay, Christopher	Texas A&M Univ.
Rasmussen, Bryan	Texas A&M Univ.

17:20-17:40	MoCT4.5
Optimal Subcooling in Vapor Compression Systems Via Extremum Seeking Control (I), pp. 843-852.	
Koeln, Justin	Univ. of Illinois at Urbana Champaign
Alleyne, Andrew G.	Univ. of Illinois at Urbana-Champaign

17:40-18:00	MoCT4.6
Decentralized Feedback Control of Smart Lighting Systems (I), pp. 853-862.	
Afshari, Sina	Rensselaer Pol. Inst.
Mishra, Sandipan	Rensselaer Pol. Inst.

MoCT5	Tent B
Instrumentation and Characterization in Bio-Systems (Invited session)	
Chair: Hahn, Jin-Oh	Univ. of Maryland
Co-Chair: Ashrafiuon, Hashem	Villanova Univ.
Organizer: Hahn, Jin-Oh	Univ. of Maryland
Organizer: Ashrafiuon, Hashem	Villanova Univ.
Organizer: Nataraj, C.	Villanova Univ.
Organizer: Asada, H. Harry	Massachusetts Inst. of Tech.

16:00-16:20	MoCT5.1
A Handheld Noninvasive Sensing Method for the Measurement of Compartment Pressures (I), pp. 863-869.	
Flegel, Christopher	Univ. of Minnesota
Singal, Kalpesh	Univ. of Minnesota
Rajamani, Rajesh	Univ. of Minnesota

16:20-16:40	MoCT5.2
Output-Boundary Regulation: High-Speed AFM Imaging Application (I), pp. 870-879.	
Boekfah, Arom	Univ. of Washington
Devasia, Santosh	Univ. of Washington

16:40-17:00	MoCT5.3
A Microscale Piezoresistive Force Sensor for Nanoindentation of Biological Cells and Tissues (I), pp. 880-884.	
Pandya, Hardik	Univ. of Maryland, Coll. Park
Kim, Hyun Tae	Mechanical Engineering, Univ. of Maryland, Coll. Park
Desai, Jaydev	Univ. of Maryland, Coll. Park

17:00-17:20	MoCT5.4
Real-Time Image Processing for Locating Veins in Mouse Tails (I), pp. 885-891.	

Chang, Yen-Chi	Univ. of California, Los Angeles
Berry-Pusey, Brittany	Crump Insitute for Molecular Imaging Univ. of California, L
Tsao, Tsu-Chin	Univ. of California Los Angeles
Chatziioannou, Arion	Crump Insitute for Molecular Imaging, Univ. of California L

17:20-17:40 MoCT5.5

Towards the Development of Optogenetically-Controlled Skeletal Muscle Actuators (I), pp. 892-896.

Kim, Hyeonyu	MIT
Neal, Devin	MIT
Asada, H. Harry	Massachusetts Inst. of Tech.

17:40-18:00 MoCT5.6

Control of Highly Organized Nanostructures in Microchannels Using Nanoliter Droplets (I), pp. 897-902.

Choi, Eunpyo	Sogang Univ.
Kwon, Kilsung	Sogang Univ.
Chang, Hyung-kwan	Sogang Univ.
Kim, Daejoong	Sogang Univ.
Park, Jungyul	Sogang Univ.

MoCT6 Room 134

Control, Monitoring, and Energy Harvesting of Vibratory Systems: Active Vibration Control-3 (Invited session)

Chair: Tang, Jiong	Univ. of Connecticut
Co-Chair: Nishimura, Hidekazu	Keio Univ.
Organizer: Zuo, Lei	Stony Brook Univ. - SUNY
Organizer: Tang, Jiong	Univ. of Connecticut
Organizer: Sipahi, Rifat	Northeastern Univ.
Organizer: Caruntu, Dumitru	Univ. of Texas Pan American
Organizer: Nishimura, Hidekazu	Keio Univ.
Organizer: Kajiwara, Itsuro	Hokkaido Univ.

16:00-16:20 MoCT6.1

Unknown Disturbance Estimator Design for Non-Minimum Phase Plants Using Parallel Feed-Forward Model (I), pp. 903-910.

Chida, Yuichi	Shinshu Univ.
Sekiguchi, Shota	Shinshu Univ.
Kobayashi, Hiroyuki	Shinshu Univ.
Ikeda, Yuichi	Shinshu Univ.

16:20-16:40 MoCT6.2

An Experimental Study on Balancing Tasks of Human Subjects in Cooperation with Invisible Artificial Partners (I), pp. 911-919.

Matsumoto, Shigeki	Utsunomiya Univ.
Yoshida, Katsutoshi	Utsunomiya Univ.

16:40-17:00 MoCT6.3

Precision Control through Vibration Suppression in Piezoelectric Stepper Response (I), pp. 920-928.

Wilcox, Scott	U. of Washington
Devasia, Santosh	Univ. of Washington

17:00-17:20 MoCT6.4

Formulation for Interaction Analysis between Continuous and Discrete Structures Subject to Moving Loads Applied to Turning (I), pp. 929-936.

Madariaga, Jon	IK4-Tekniker
Tsao, Tsu-Chin	Univ. of California Los Angeles
Ruiz, Ismael	IK4-Tekniker

17:20-17:40 MoCT6.5

Adaptive Control of Acoustic Waves in Flexible Structure (I), pp. 937-943.

Ji, Chunhua	Univ. of Connecticut
Gao, Robert	Univ. of Connecticut
Fan, Zhaoyan	Univ. of Connecticut
Liang, Kenneth	Schlumberger-Doll Res. Center
Pabon, Jahir	Schlumberger-Doll Res. Center

17:40-18:00 MoCT6.6

Fine Structure of Pareto Front of Multi-Objective Optimal Feedback Control Design (I), pp. 944-949.

Sun, Jian-Qiao	UC Merced

MoCT7 Room 138

Nonlinear Estimation and Control (Contributed session)

Chair: Djurdjanovic, Dragan	Univ. of Texas
Co-Chair: Bevly, David	Auburn Univ.

16:00-16:20 MoCT7.1

Robust Observer Design for Lipschitz Nonlinear Systems with Parametric Uncertainty, pp. 950-959.

Wang, Yan	Auburn Univ.
Bevly, David	Auburn Univ.

16:20-16:40 MoCT7.2

Robust Disturbance Rejection for a Class of Nonlinear Systems Using Disturbance Observers, pp. 960-967.

El Shaer, Ahmed H.	LineStream Tech.
Bajodah, Abdulrahman	King Abdulaziz Univ.

16:40-17:00 MoCT7.3

Model-Predictive Control and Closed-Loop Stability Considerations for Nonlinear Plants Described by Local ARX-Type Models, pp. 968-977.

Cholette, Michael	Queensland Univ. of Tech.
Djurdjanovic, Dragan	Univ. of Texas

17:00-17:20 MoCT7.4

Nonparametric Identification of Hammerstein Systems Using Orthogonal Basis Functions As Ersatz Nonlinearities, pp. 978-985.

Aljanaideh, Khaled	Univ. of Michigan
Bernstein, Dennis S.	Univ. of Michigan

17:20-17:40 MoCT7.5

An Adaptive Control Method with Low-Resolution Encoder, pp. 986-995.

Zhang, Zhenyu	Western Digital Corp.
Olgac, Nejat	Univ. of Connecticut

17:40-18:00 MoCT7.6

Asymptotic Stability Method for PID Controller Tuning in a Backhoe Machine, pp. 996-1003.

Mastalli, Carlos Eduardo	Simon Bolivar Univ.
Ralev, Dimitar	Simon Bolivar Univ.
Certad, Novel	Simon Bolivar Univ.
Fernandez, Gerardo	Simon Bolivar Univ.

Technical Program for Tuesday October 22, 2013

TuAT1	Paul Brest East
Vehicle Dynamics and Control (Contributed session)	
Chair: Wang, Junmin	The Ohio State Univ.
Co-Chair: Ayalew, Beshah	Clemson Univ.

10:15-10:35 — TuAT1.1

Network Control of Vehicle Lateral Dynamics with Control Allocation and Dynamic Message Priority Assignment, pp. 1004-1013.

Shuai, Zhibin	Ohio State Univ.
Zhang, Hui	The Ohio State Univ.
Wang, Junmin	The Ohio State Univ.
Li, Jianqiu	Tsinghua Univ.
Ouyang, Minggao	Tsinghua Univ.

10:35-10:55 — TuAT1.2

Adaptive Traction Control for Non-Rigid Tire-Wheel Systems, pp. 1014-1023.

Adcox, John	Clemson Univ.
Ayalew, Beshah	Clemson Univ.

10:55-11:15 — TuAT1.3

Vehicle Roll Stabilization Enhancement Using a Variable Stiffness Architecture: Kinematic Control, pp. 1024-1033.

Anubi, Olugbenga	Univ. of Florida
Crane, Carl	Univ. of Florida

11:15-11:35 — TuAT1.4

Cooperative Trajectory Planning for Automated Farming, pp. 1034-1041.

Remeikas, Charles	Univ. of Central Florida
Xu, Yunjun	Univ. of Central Florida
Jayasuriya, Suhada	Univ. of Central Florida

11:35-11:55 — TuAT1.5

The Role of Model Fidelity in Model Predictive Control Based Hazard Avoidance in Unmanned Ground Vehicles Using LIDAR Sensors, pp. 1042-1051.

Liu, Jiechao	Univ. of Michigan
Jayakumar, Paramsothy	U.S. Army RDECOM-TARDEC
Overholt, James L.	U.S. Army RDECOM-TARDEC
Stein, Jeffrey L.	Univ. of Michigan
Ersal, Tulga	Univ. of Michigan

11:55-12:15 — TuAT1.6

*Vehicle Dynamic Estimation Based on Coupling Unscented Particle Filter**.

Lin, Fen	Nanjing Univ. of Aeronautics and Astronautics

TuAT2	Room 123
Cooperative and Networked Control (Contributed session)	
Chair: Milutinovic, Dejan	Univ. of California Santa Cruz
Co-Chair: Patel, Rushabh	Univ. of California Santa Barbara

10:15-10:35 — TuAT2.1

The Dubins Traveling Salesperson Problem with Stochastic Dynamics, pp. 1052-1058.

Anderson, Ross	Univ. of California, Santa Cruz
Milutinovic, Dejan	Univ. of California Santa Cruz

10:35-10:55 — TuAT2.2

Hybrid Particle Swarm – Tabu Search Optimization Algorithm for Parameter Estimation, pp. 1059-1067.

Sebastian, Anish	Idaho State Univ.
Schoen, Marco	Idaho State Univ.

10:55-11:15 — TuAT2.3

Centroidal Area-Constrained Partitioning for Robotic Networks, pp. 1068-1072.

Patel, Rushabh	Univ. of California Santa Barbara
Frasca, Paolo	Pol. di Torino
Bullo, Francesco	Univ. California at Santa Barbara

11:15-11:35 — TuAT2.4

Guaranteed Consensus in Radar Deception with a Phantom Track, pp. 1073-1079.

Jayasuriya, Suhada	Univ. of Central Florida
Hajieghrary, Hadi	Univ. of Central Florida

11:35-11:55 — TuAT2.5

Model-Based Compensation for Burst Message Loss in Wireless Networked Control Systems: Experimental Results, pp. 1080-1088.

Godoy, Eduardo Paciencia	UNESP - São Paulo State Univ.
Scorzoni, Fernando	Univ. of São Paulo
Colon, Diego	São Paulo State Univ.
Porto, Arthur Jose Vieira	Univ. of São Paulo

11:55-12:15 — TuAT2.6

Bandwidth Allocation of Networked Control Systems with Exponential Approximation, pp. 1089-1097.

Dong, Jiawei	Texas A&M Univ.
Kim, Won-jong	Texas A&M Univ.

TuAT3	Tent A
Nonholonomic Systems (Contributed session)	
Chair: Kelly, Scott	Univ. of North Carolina at Charlotte
Co-Chair: Nersesov, Sergey G.	Villanova Univ.

10:15-10:35 — TuAT3.1

Mechanics and Control of a Terrestrial Vehicle Exploiting a Nonholonomic Constraint for Fishlike Locomotion, pp. 1098-1102.

Dear, Tony	Carnegie Mellon Univ.
Kelly, Scott	Univ. of North Carolina at Charlotte
Travers, Matthew	Carnegie Mellon
Choset, Howie	Carnegie Mellon Univ.

10:35-10:55 — TuAT3.2

Sliding Mode Coordination Control Design for Multiagent Systems, pp. 1103-1112.

Ghasemi, Masood	Villanova Univ.
Nersesov, Sergey G.	Villanova Univ.

10:55-11:15 — TuAT3.3

Energy-Based Limit Cycle Compensation for Dynamically Balancing Wheeled Inverted Pendulum Machines, pp. 1113-1120.

Vasudevan, Hari	Yale Univ.
Dollar, Aaron	Yale Univ.
Morrell, John	Yale Univ.

11:15-11:35 — TuAT3.4

Trajectory Optimization for Nonholonomic Vehicles on Non-Flat Terrains Using Shooting and Collocation Methods, pp. 1121-1129.

Chatzigeorgiou, Dimitris — MIT

11:35-11:55 — TuAT3.5

Optimal Gait Design for Systems with Drift on SO(3), pp. 1130-1136.

Travers, Matthew — Carnegie Mellon
Choset, Howie — Carnegie Mellon Univ.

11:55-12:15 — TuAT3.6

Snakeboard Motion Planning with Local Trajectory Information, pp. 1137-1144.

Dear, Tony — Carnegie Mellon Univ.
Hatton, Ross — Oregon State Univ.
Travers, Matthew — Carnegie Mellon
Choset, Howie — Carnegie Mellon Univ.

TuAT4 — Paul Brest West

Estimation and Identification of Energy Systems (Invited session)

Chair: Moura, Scott — UC San Diego
Co-Chair: Kim, Youngki — Univ. of Michigan
Organizer: McKahn, Denise A. — Smith Coll.
Organizer: Moura, Scott — UC San Diego

10:15-10:35 — TuAT4.1

Estimating the Concentration Imbalance of a Vanadium Redox Flow Battery with Crossover Using a Constrained Extended Kalman Filter (I), pp. 1145-1151.

Yu, Victor — The Univ. of Texas at Austin
Chen, Dongmei — The Univ. of Texas at Austin

10:35-10:55 — TuAT4.2

Modeling Heterogeneous Populations of Thermostatically Controlled Loads Using Diffusion-Advection PDEs (I), pp. 1152-1159.

Moura, Scott — UC San Diego
Ruiz, Victor — Univ. of California, San Diego
Bendsten, Jan — Aalborg Univ.

10:55-11:15 — TuAT4.3

Broad Frequency Vibration Energy Harvesting Control Approach Based on the Maximum Power Transfer Theorem (I), pp. 1160-1168.

Pedchenko, Alexander — Vanderbilt Univ.
Barth, Eric J. — Vanderbilt Univ.

11:15-11:35 — TuAT4.4

Nonlinear State Estimation of Moving Boundary Heat Exchanger Models for Organic Rankine Cycle Waste Heat Recovery (I), pp. 1169-1177.

Luong, David — Univ. of California, Los Angeles
Tsao, Tsu-Chin — Univ. of California Los Angeles

11:35-11:55 — TuAT4.5

Maximum Power Estimation of Lithium-Ion Batteries Accounting for Thermal and Electrical Constraints, pp. 1178-1185.

Kim, Youngki — Univ. of Michigan
Mohan, Shankar — Univ. of Michigan
Siegel, Jason B. — Univ. of Michigan
Stefanopoulou, Anna G. — Univ. of Michigan

11:55-12:15 — TuAT4.6

Online Simultaneous State Estimation and Parameter Adaptation for Building Predictive Control (I), pp. 1186-1195.

Maasoumy, Mehdi — UC Berkeley
Moridian, Barzin — Michigan Tech. Univ.
Razmara, Meysam — Michigan Tech. Univ.
Shahbakhti, Mahdi — Michigan Tech. Univ.
Sangiovanni Vincentelli, Alberto — Univ. OF CALIFORNIA BERKELEY

TuAT5 — Tent B

Biomedical Robots and Rehabilitation (Contributed session)

Chair: Barth, Eric J. — Vanderbilt Univ.
Co-Chair: Rastgaar, Mohammad — Michigan Tech.

10:15-10:35 — TuAT5.1

Robust Maneuver Based Design of Passive-Assist Devices for Augmenting Robotic Manipulator Joints, pp. 1196-1204.

Brown, W. Robert — Univ. of Michigan
Ulsoy, A. Galip — Univ. of Michigan

10:35-10:55 — TuAT5.2

On the Design and Control of Knee Exoskeleton (I), pp. 1205-1210.

Tung, Wayne Yi-Wei — Univ. of California, Berkeley
Kazerooni, Homayoon — Univ. of California at Berkeley
Hyun, Dong Jin — Massachusetts Inst. of Tech.
McKinley, Stephen — UC Berkeley

10:55-11:15 — TuAT5.3

Optimized Control of Different Actuation Strategies for FES and Orthosis Aided Gait (I), pp. 1211-1220.

Kirsch, Nicholas — Univ. of Pittsburgh
Alibeji, Naji A — Univ. of Pittsburgh
Sharma, Nitin — Univ. of Pittsburgh

11:15-11:35 — TuAT5.4

Regulation of 3D Human Arm Impedance through Muscle Co-Contraction, pp. 1221-1229.

Patel, Harshil — Arizona State Univ.
O'Neill, Gerald, D — Arizona State Univ.
Artemiadis, Panagiotis — Arizona State Univ.

11:35-11:55 — TuAT5.5

Ankle Angles During Step Turn and Straight Walk: Implications for the Design of a Steerable Ankle-Foot Prosthetic Robot, pp. 1230-1234.

Ficanha, Evandro — Michigan Technological Univ.
Rastgaar, Mohammad — Michigan Tech.
Moridian, Barzin — Michigan Tech. Univ.
Mahmoudian, Nina — Michigan Tech. Univ.

11:55-12:15 — TuAT5.6

Design of a Stirling Thermocompressor for a Pneumatically Actuated Ankle-Foot Orthosis, pp. 1235-1243.

Kumar, Nithin — Vanderbilt Univ.
Hofacker, Mark — Vanderbilt Univ.
Barth, Eric J. — Vanderbilt Univ.

TuAT6 — Room 134

Control, Monitoring, and Energy Harvesting of Vibratory Systems: Analysis and Passive Control (Invited session)

Chair: Tang, Jiong — Univ. of Connecticut
Co-Chair: Nishimura, Hidekazu — Keio Univ.
Organizer: Zuo, Lei — Stony Brook Univ. - SUNY
Organizer: Tang, Jiong — Univ. of Connecticut
Organizer: Sipahi, Rifat — Northeastern Univ.
Organizer: Caruntu, Dumitru — Univ. of Texas Pan American
Organizer: Nishimura, — Keio Univ.

Hidekazu

Organizer: Kajiwara, Itsuro — Hokkaido Univ.

10:15-10:35 — TuAT6.1

Study on Novel Tuned Mass Dampers Utilizing Plural Auxiliary Masses to Expand Vibration Suppression Performance under the Conditions of Limited Mass Ratio (I), pp. 1244-1249.

Watanabe, Toru — Nihon Univ.
Usuki, Daiki — Graduate Student, School of Science and Tech. Nihon Univ.
Seto, Kazuto — Seto Vibration Control Lab.

10:35-10:55 — TuAT6.2

Reduced Order Model of Parametric Resonance of Electrostatically Actuated CNT Cantilever Resonators (I), pp. 1250-1254.

Caruntu, Dumitru — Univ. of Texas Pan American
Luo, Le — Univ. of Texas Pan American

10:55-11:15 — TuAT6.3

Analysis of a Bi-Harmonic Tapping Mode for Atomic Force Microscopy (I), pp. 1255-1262.

Loganathan, Muthukumaran — Missouri Univ. of Science and Tech.
Bristow, Douglas A. — Missouri Univ. of Science and Tech.

11:15-11:35 — TuAT6.4

Perturbing Structural Design towards Minimizing Variation in Vibratory Response (I), pp. 1263-1267.

Zhou, Kai — Univ. of Connecticut
Tang, Jiong — Univ. of Connecticut

11:35-11:55 — TuAT6.5

Detection of Contact-Type Damages by Utilizing Nonlinear Piezoelectric Impedance Modulation of Self-Excited Structures (I), pp. 1268-1274.

Masuda, Arata — Kyoto Inst. of Tech.
Ogawa, Yuya — Kyoto Inst. of Tech.
Sone, Akira — Kyoto Inst. of Tech.

11:55-12:15 — TuAT6.6

Study on the Vibration Response of Axially Moving Continua (I), pp. 1275-1284.

Chung, Chunhui — National Taiwan Univ. of Science and Tech.
Kao, Imin — Stony Brook Univ.

TuAT7 — Room 138

Optimization and Optimal Control (Contributed session)

Chair: Tulpule, Punit — Iowa State Univ.
Co-Chair: Li, Yaoyu — Univ. of Texas at Dallas

10:15-10:35 — TuAT7.1

Discrimination of Steady State and Transient State of Extremum Seeking Control Via Sinusoidal Detection, pp. 1285-1294.

Mu, Baojie — The Univ. of Texas at Dallas
Li, Yaoyu — Univ. of Texas at Dallas
Seem, John E. — Johnson Controls Inc.

10:35-10:55 — TuAT7.2

Governing Parameter Changes in Nonlinear Parameter-Dependent Optimization Problems, pp. 1295-1304.

Gupta, Rohit — Univ. of Michigan
Kolmanovsky, Ilya — The Univ. of Michigan, Ann Arbor

10:55-11:15 — TuAT7.3

Optimal Compression of a Generalized Prandtl-Ishlinskii Operator in Hysteresis Modeling, pp. 1305-1314.

Zhang, Jun — Michigan State Univ.
Merced, Emmanuelle — Michigan State Univ.
Sepulveda, Nelson — Michigan State Univ.
Tan, Xiaobo — Michigan State Univ.

11:15-11:35 — TuAT7.4

A Gradient-Based Method for Team Evasion, pp. 1315-1323.

Liu, Shih-Yuan — Univ. of California, Berkeley
Zhou, Zhengyuan — Univ. of California, Berkeley
Tomlin, Claire J. — UC Berkeley
Hedrick, Karl — Univ. of California at Berkeley

11:35-11:55 — TuAT7.5

Bmi Based Robust Optimal Control Synthesis Via Sensitivity Minimization, pp. 1324-1332.

Tulpule, Punit — Iowa State Univ.
Kelkar, Atul — Iowa State Univ.

11:55-12:15 — TuAT7.6

Research on an Approximate Model Based Virtual Calibration Method with Doe and Optimization Algorithm for Transmission Control Unit, pp. 1333-1338.

Wu, Guangqiang — Tongji Univ.
Sun, Lu — Tongji Univ.
Zhu, Sheng — Tongji Univ.
Zhang, Kuankuan — Tongji Univ.

TuBT1 — Paul Brest East

Automotive Control Systems (Contributed session)

Chair: Canova, Marcello — The Ohio State Univ.
Co-Chair: Shahbakhti, Mahdi — Michigan Tech. Univ.

13:30-13:50 — TuBT1.1

Multi-Input Observer for Estimation of Compressor Flow, pp. 1339-1343.

Kalabic, Uros — Univ. of Michigan
Kolmanovsky, Ilya — The Univ. of Michigan, Ann Arbor
Buckland, Julia — Ford Motor Company

13:50-14:10 — TuBT1.2

Rate-Based Contractive Model Predictive Control of Diesel Air Path, pp. 1344-1348.

Huang, Mike — Univ. of Michigan
Butts, Kenneth — Toyota Motor Engineering and Manufacturing, NA
Polavarapu, Srinivas — Belcan Corp.
Kolmanovsky, Ilya — The Univ. of Michigan, Ann Arbor
Nakada, Hayato — Toyota Motor Corp.

14:10-14:30 — TuBT1.3

On-Line Fault Detection and Isolation (FDI) for the Exhaust Path of a Turbocharged SI Engine (I), pp. 1349-1358.

Salehi, Rasoul — Sharif Univ. of Tech.
Shahbakhti, Mahdi — Michigan Tech. Univ.
Alasty, Aria — Sharif Univ. of Tech.
Vossoughi, Gholamreza — Sharif Univ. of Tech.

14:30-14:50 — TuBT1.4

Lumped-Parameter Modeling of an Automotive Air Conditioning System for Energy Optimization and Management, pp. 1359-1366.

Zhang, Quansheng — the Ohio State Univ.

Canova, Marcello — The Ohio State Univ.

14:50-15:10 TuBT1.5

Conceptual Design and Simulation of the Traction Control System of a High Performance Electric Vehicle (I), pp. 1367-1375.

Nuñez, Juan Sebastian — Univ. de los Andes
Muñoz, Luis Ernesto — Univ. de los Andes

15:10-15:30 TuBT1.6

Nonlinear Clutch Engagement Control, pp. 1376-1380.

Chen, Jyh-Shin — General Motors
Zhu, Yongjie — GM

TuBT2 Room 123

Haptics and Hand Motion (Contributed session)

Chair: O'Malley, Marcia — Rice Univ.
Co-Chair: Okamura, Allison — Stanford Univ.

13:30-13:50 TuBT2.1

User-Independent Hand Motion Classification with Electromyography, pp. 1381-1386.

Gibson, Alison — Arizona State Univ.
Ison, Mark — Arizona State Univ.
Artemiadis, Panagiotis — Arizona State Univ.

13:50-14:10 TuBT2.2

A Method for Selecting Velocity Filter Cutoff Frequency for Maximizing Impedance Width Performance in Haptic Interfaces, pp. 1387-1394.

Chawda, Vinay — Rice Univ.
Celik, Ozkan — San Francisco State Univ.
O'Malley, Marcia — Rice Univ.

14:10-14:30 TuBT2.3

Haptic Glove Using Compression-Induced Friction Torque, pp. 1395-1401.

Kuroda, Yoshihiro — Osaka Univ.
Shigeta, Yu — Osaka Univ.
Imura, Masataka — Osaka Univ.
Uranishi, Yuki — Osaka Univ.
Oshiro, Osamu — Osaka Univ.

14:30-14:50 TuBT2.4

Evaluation of Friction Models for Haptic Devices, pp. 1402-1410.

Ahmad, Aftab — KTH, Royal Inst. of Tech.
Andersson, Kjell — KTH, Royal Inst. of Tech.
Sellgren, Ulf — KTH Royal Inst. of Tech.
Boegli, Max — KU Leuven

14:50-15:10 TuBT2.5

Model-Mediated Teleoperation with Predictive Models and Relative Tracking, pp. 1411-1415.

Winck, Ryder C. — Stanford Univ.
Okamura, Allison — Stanford Univ.

15:10-15:30 TuBT2.6

A Haptic System for Educational Games: Design and Application-Specific Kinematic Optimization, pp. 1416-1420.

Kessler, Jeffrey A. — Stanford Univ.
Lovelace, R. Curtis — Stanford Univ.
Okamura, Allison — Stanford Univ.

TuBT3 Tent A

Vehicles and Human Robotics (Contributed session)

Chair: Fathy, Hosam K. — The Pennsylvania State Univ.
Co-Chair: Singhose, William — Georgia Inst. of Tech.

13:30-13:50 TuBT3.1

An Interactive Multimedia Framework for Education on Vehicle Electrification, pp. 1421-1430.

Rothenberger, Michael — The Pennsylvania State Univ.
Fathy, Hosam K. — The Pennsylvania State Univ.

13:50-14:10 TuBT3.2

A System-Dynamics-Based Hazard Analysis of Inverted-Pendulum Human Transporters, pp. 1431-1440.

Adams, Christopher — Georgia Inst. of Tech.
Singhose, William — Georgia Inst. of Tech.
Kim, Dooroo — Georgia Inst. of Tech.

14:10-14:30 TuBT3.3

Navigation of an Underwater Remotely Operated Vehicle Based on Extended Kalman Filter (I), pp. 1441-1449.

Martinez Carvajal, Blanca Viviana — Univ. Industrial de Santander
Sierra Bueno, Daniel Alfonso — Univ. Industrial de Santander
Villamizar Mejia, Rodolfo — Univ. Industrial de Santander

14:30-14:50 TuBT3.4

Simulation of the Dynamic Behavior of Ships Based on Slender-Body Theory (sbt) (I), pp. 1450-1459.

Tascon Muñoz, Oscar Dario — COTECMAR
Mora Paz, Jaime David — COTECMAR
Algarin Roncallo, Roberto — COTECMAR

14:50-15:10 TuBT3.5

Bio-Inspired Robot Control for Human-Robot Bi-Manual Manipulation, pp. 1460-1467.

Warren, Stephen — Arizona State Univ.
Artemiadis, Panagiotis — Arizona State Univ.

15:10-15:30 TuBT3.6

Modeling and Simulation of Human Walking with Wearable Powered Assisting Device (I), pp. 1468-1473.

Slavnić, Siniša — Univ. of Bremen
Leu, Adrian — Univ. of Bremen
Ristić-Durrant, Danijela — Univ. of Bremen
Gräser, Axel — Univ. of Bremen, Inst. of Automation (IAT)

TuBT4 Paul Brest West

Battery Systems (Contributed session)

Chair: Peng, Huei — Univ. of Michigan
Co-Chair: Fathy, Hosam K. — The Pennsylvania State Univ.

13:30-13:50 TuBT4.1

Approximations for Partial Differential Equations Appearing in Li-Ion Battery Models, pp. 1474-1483.

Chaturvedi, Nalin A. — Robert Bosch LLC
Christensen, Jake — Robert Bosch LLC
Klein, Reinhardt — Robert Bosch LLC
Kojic, Aleksandar — Robert Bosch Res. and Tech. Center North America

13:50-14:10 TuBT4.2

Battery State of Health and Charge Estimation Using Polynomial Chaos Theory, pp. 1484-1493.

Bashash, Saeid	Pennsylvania State Univ.
Fathy, Hosam K.	The Pennsylvania State Univ.

14:10-14:30	TuBT4.3

An Open-Circuit-Voltage Model of Lithium-Ion Batteries for Effective Incremental Capacity Analysis, pp. 1494-1501.

Weng, Caihao	Univ. of Michigan
Sun, Jing	Univ. of Michigan
Peng, Huei	Univ. of Michigan

14:30-14:50	TuBT4.4

Hybrid Electric Vehicle Energy Management with Battery Thermal Considerations Using Multi-Rate Dynamic Programming, pp. 1502-1511.

Johri, Rajit	Ford Motor Company
Liang, Wei	Ford Motor Company
McGee, Ryan	Ford Motor Company

14:50-15:10	TuBT4.5

Cost-Effective Energy Management for Hybrid Electric Heavy-Duty Truck Including Battery Aging, pp. 1512-1519.

Pham, T.H.	Eindhoven Univ. of Tech.
Kessels, J.T.B.A.	Eindhoven Univ. of Tech.
van den Bosch, P.P.J.	Eindhoven Univ. of Tech.
Huisman, R.G.M.	DAF Trucks N.V.

15:10-15:30	TuBT4.6

Comprehensive Battery Equivalent Circuit Based Model for Battery Management Application, pp. 1520-1529.

Tong, Shijie	Univ. of California, Davis
Klein, Matthew	Univ. of California, Davis
Park, Jae Wan	UC Davis

TuBT5	Tent B

Bio-Medical and Bio-Mechanical Systems (Contributed session)

Chair: Leonessa, Alexander	Virginia Tech.
Co-Chair: Artemiadis, Panagiotis	Arizona State Univ.

13:30-13:50	TuBT5.1

Robot-Guided Sheaths (RoGS) for Percutaneous Access to the Pediatric Kidney: Patient-Specific Design and Preliminary Results, pp. 1530-1534.

Morimoto, Tania	Stanford Univ.
Hsieh, Michael	Stanford Univ.
Okamura, Allison	Stanford Univ.

13:50-14:10	TuBT5.2

Development of a Master-Slave Robotic System for Mri-Guided Intracardiac Interventions, pp. 1535-1542.

Salimi, Amirhossein	Univ. of Houston
Ramezanifar, Amin	Univ. of Houston
Mohammadpour, Javad	Univ. of Georgia
Grigoriadis, Karolos M.	Univ. of Houston

14:10-14:30	TuBT5.3

Beyond User-Specificity for EMG Decoding Using Multiresolution Muscle Synergy Analysis, pp. 1543-1548.

Ison, Mark	Arizona State Univ.
Artemiadis, Panagiotis	Arizona State Univ.

14:30-14:50	TuBT5.4

Development of Electromagnetic Stimulation System As Treatment for Muscle Activation, pp. 1549-1553.

Jaramillo, Paola	Virginia Tech.
Shoemaker, Adam	Virginia Tech.
Burks, William	Virginia Tech.
Tran, Michelle	Virginia Tech.
Leonessa, Alexander	Virginia Tech.

14:50-15:10	TuBT5.5

Design and Modeling of a Series Elastic Element for Snake Robots, pp. 1554-1558.

Rollinson, David	Carnegie Mellon Univ.
Ford, Steven	Carnegie Mellon Univ.
Brown, H. Benjamin	Carnegie Mellon Univ.
Choset, Howie	Carnegie Mellon Univ.

15:10-15:30	TuBT5.6

Dynamic Modeling of a Compliant Tail-Propelled Robotic Fish, pp. 1559-1567.

Kopman, Vladislav	Pol. Inst. of New York Univ.
Laut, Jeffrey	Pol. Inst. of New York Univ.
Porfiri, Maurizio	Pol. Inst. of NYU
Acquaviva, Francesco	Pol. di Bari
Rizzo, Alessandro	Pol. Inst. of NYU

TuBT6	Room 134

Control, Monitoring, and Energy Harvesting of Vibratory Systems: Energy Harvesting (Invited session)

Chair: Zuo, Lei	Stony Brook Univ. - SUNY
Co-Chair: Kajiwara, Itsuro	Hokkaido Univ.
Organizer: Zuo, Lei	Stony Brook Univ. - SUNY
Organizer: Tang, Jiong	Univ. of Connecticut
Organizer: Sipahi, Rifat	Northeastern Univ.
Organizer: Caruntu, Dumitru	Univ. of Texas Pan American
Organizer: Nishimura, Hidekazu	Keio Univ.
Organizer: Kajiwara, Itsuro	Hokkaido Univ.

13:30-13:50	TuBT6.1

Ocean Wave Energy Converters and Control Methodologies (I), pp. 1568-1577.

Xie, Jingjin	Stony Brook Univ.
Zuo, Lei	Stony Brook Univ. - SUNY

13:50-14:10	TuBT6.2

Research on Resonant Frequency and Output Power of Piezoelectric Energy-Harvesting Micro-Device (I), pp. 1578-1584.

Gao, Yuji	Tianjin Univ.
Leng, Yong-gang	Tianjin Univ.
Shen, Linchen	China Agricultural Univ.
Guo, Yan	Tianjin Univ.

14:10-14:30	TuBT6.3

The Application of Electrode Design in Vibrating Piezoceramic Plate for Energy Harvesting System (I), pp. 1585-1594.

Huang, Yu-Hsi	National Taiwan Univ. of Science and Tech.
Chao, Ching-Kong	National Taiwan Univ. of Science and Tech.
Chou, Wan-Ting	National Taiwan Univ. of Science and Tech.
Ma, Chien-Ching	National Taiwan Univ.

14:30-14:50	TuBT6.4

Further Application of Stochastic Resonance for Energy Harvesting

(I), pp. 1595-1601.

Su, Dongxu	Univ. of Tokyo
Nakano, Kimihiko	Univ. of Tokyo
Hu, Honggang	The Univ. of Tokyo
Cartmell, Matthew P	Univ. of Sheffield
Ohori, Masanori	The Univ. of Tokyo
Zheng, Rencheng	The Univ. of Tokyo

14:50-15:10 TuBT6.5

Damage Identification in Collocated Structural Systems Using Structural Markov Parameters (I), pp. 1602-1611.

Bighamian, Ramin	Univ. of Maryland
Mirdamadi, Hamid Reza	Isfahan Univ. of Tech.
Hahn, Jin-Oh	Univ. of Maryland

15:10-15:30 TuBT6.6

Development of a Variable Electromotive-Force Generator with an Active Control System (I), pp. 1612-1621.

Zhu, Weidong	Univ. of Maryland, Baltimore County
Goudarzi, Navid	Univ. of Maryland, Baltimore County
Wang, Xuefeng	Univ. of Maryland, Baltimore County
Kendrick, Phillip	Univ. of Maryland, Baltimore County

TuBT7 Room 138

Variable Structure/ Sliding-Mode Control (Contributed session)

Chair: Tomizuka, Masayoshi	Univ. of California, Berkeley
Co-Chair: Choi, Changrak	MIT

13:30-13:50 TuBT7.1

Robust Control of an Hvac System Via a Super-Twisting Sliding Mode Technique, pp. 1622-1627.

Kianfar, Kaveh	Simon Fraser Univ.
Izadi-Zamanabadi, Roozbeh	Danfoss A/S
Saif, Mehrdad	Univ. of Windsor

13:50-14:10 TuBT7.2

Optimal Sliding Mode Gaussian Controller for Hydropower Plant with Grid Dynamics, pp. 1628-1634.

Rittenhouse, Benjamin	Pennsylvania State Univ.
Sinha, Alok	Penn State Univ.

14:10-14:30 TuBT7.3

Model Predictive Sliding Mode Control — for Constraint Satisfaction and Robustness, pp. 1635-1644.

Wang, Yizhou	Univ. of California at Berkeley
Chen, Wenjie	Univ. of California at Berkeley
Tomizuka, Masayoshi	Univ. of California, Berkeley
Alsuwaidan, Badr	King Abdulaziz City for Science and Tech.

14:30-14:50 TuBT7.4

Control of Inverted Pendulum Using Only Vertical Force through Harmonic Oscillation, pp. 1645-1654.

Choi, Changrak	MIT

14:50-15:10 TuBT7.5

Backward-Euler Discretization of Second-Order Sliding Mode Control and Super-Twisting Observer for Accurate Position Control, pp. 1655-1662.

Xiong, Xiaogang	Kyushu Univ.
Kikuuwe, Ryo	Kyushu Univ.
Yamamoto, Motoji	Kyushu Univ.

15:10-15:30 TuBT7.6

*A Fixed Time Sliding Mode Observer for Flux and Load in Induction Motors**.

Sánchez-Torres, Juan Diego	CINVESTAV-IPN GDL
Rubio Astorga, Guillermo	CINVESTAV-IPN GDL
Cañedo Catañeda, José Manuel	CINVESTAV-IPN GDL
Loukianov, Alexander G.	CINVESTAV IPN GDl

WeAT1	Paul Brest East
Intelligent Transportation Systems (Invited session)	
Chair: Langari, Reza	Texas A&M Univ.
Co-Chair: Kolodziej, Jason	Rochester Inst. of Tech.
Organizer: Scacchioli, Annalisa	New York Univ.
Organizer: Kolodziej, Jason	Rochester Inst. of Tech.
Organizer: Canova, Marcello	The Ohio State Univ.
Organizer: Shahbakhti, Mahdi	Michigan Tech. Univ.
Organizer: Yan, Fengjun	McMaster Univ.
Organizer: Hall, Carrie	Purdue Univ.

10:15-10:35 WeAT1.1

Digital Effects and Delays in Connected Vehicles: Linear Stability and Simulations (I), pp. 1663-1672.

Qin, Wubing B.	Univ. of Michigan, Ann Arbor
Orosz, Gabor	Univ. of Michigan

10:35-10:55 WeAT1.2

Self-Reconfigurable Control System for Autonomous Vehicles (I), pp. 1673-1678.

Shoureshi, Rahmat	Univ. of Denver
Lim, Sun-Wook	New York Inst. of Tech.
Aasted, Christopher	Harvard Medical School / Boston Children's Hospital

10:55-11:15 WeAT1.3

A Stackelberg Game Theoretic Driver Model for Merging (I), pp. 1679-1686.

Yoo, Je Hong	Texas A&M Univ.
Langari, Reza	Texas A&M Univ.

11:15-11:35 WeAT1.4

Hybrid Powertrain Optimization with Real-Time Traffic Information (I), pp. 1687-1696.

Mohd Zulkefli, Mohd Azrin	Univ. of Minnesota
Zheng, Jianfeng	Univ. of Minnesota
Sun, Zongxuan	Univ. of Minnesota
Liu, Henry	Univ. of Minnesota

11:35-11:55 WeAT1.5

Stability of Connected Vehicle Platoons with Delayed Acceleration Feedback (I), pp. 1697-1706.

Ge, Jin I.	Univ. of Michigan, Ann Arbor
Avedisov (Jr.), Sergei S.	Univ. of Michigan, Ann Arbor
Orosz, Gabor	Univ. of Michigan

11:55-12:15 WeAT1.6

Accounting for Parametric Model Uncertainty in Collision Avoidance for Unmanned Vehicles Using Sparse Grid Interpolation, pp. 1707-1714.

Noble, Sarah	United States Naval Acad.
Esposito, Joel	US Naval Acad.

WeAT2	Room 123
Robotic Manipulators (Contributed session)	
Chair: Krovi, Venkat N.	SUNY Buffalo
Co-Chair: Mascaro, Stephen	Univ. of Utah

10:15-10:35 WeAT2.1

Optimal Control Algorithm for Multi-Input Binary-Segmented SMA Actuators Applied to a Multi-DOF Robot Manipulator, pp. 1715-1722.

Mollaei, Mohammadreza	Univ. OF UTAH
Mascaro, Stephen	Univ. of Utah

10:35-10:55 WeAT2.2

Design of Input Shaping Control for Planar Parallel Manipulators, pp. 1723-1731.

Sathia Narayanan, Madusudanan	School of Engineering, Univ. at Buffalo
Krovi, Venkat N.	SUNY Buffalo

10:55-11:15 WeAT2.3

Maneuver Based Design of Passive-Assist Devices: A Comparison of Parallel and Serial Systems, pp. 1732-1741.

Brown, W. Robert	Univ. of Michigan
Ulsoy, A. Galip	Univ. of Michigan

11:15-11:35 WeAT2.4

Evaluation and Design of Manipulators Based on a Dynamic Accuracy Index Considering Task-Directions, pp. 1742-1750.

Kai, Yoshihiro	Tokai Univ.

11:35-11:55 WeAT2.5

Kinematic Synthesis of Minimally Actuated Multi-Loop Planar Linkages with Second Order Motion Constraints for Object Grasping (I), pp. 1751-1758.

Soh, Gim Song	Singapore Univ. of Tech. and Design
Robson, Nina	California State Univ. Fullerton

11:55-12:15 WeAT2.6

A Feed Forward Neural Network for Solving the Inverse Kinetics of Non-Constant Curvature Soft Manipulators Driven by Cables, pp. 1759-1768.

Giorelli, Michele	Scuola Superiore Sant'Anna
Renda, Federico	Scuola Superiore Sant'Anna
Ferri, Gabriele	Scuola Superiore Sant'Anna
Laschi, Cecilia	Scuola Superiore Sant'Anna

WeAT3	Tent A
Piezoelectric Actuation and Nanoscale Control (Contributed session)	
Chair: Zou, Qingze	Rutgers, the State Univ. of New Jersey
Co-Chair: Oldham, Kenn	Univ. of Michigan

10:15-10:35 WeAT3.1

Flatness-Based Open Loop Command Tracking for Quasistatic Microscanners, pp. 1769-1773.

Janschek, Klaus	Tech. Univ. Dresden
Schroedter, Richard	Fraunhofer Inst. for Photonic Microsystems, Dresden
Sandner, Thilo	Fraunhofer Inst. for Photonic Microsystems, Dresden

10:35-10:55 WeAT3.2

Two Degree-Of-Freedom Hysteresis Compensation for a Dynamic Mirror with Antagonistic Piezoelectric Stack Actuation, pp. 1774-1783.

Mynderse, James A.	Lawrence Tech. Univ.
Chiu, George T.-C.	Purdue Univ.

10:55-11:15 WeAT3.3

Iterative-Control-Based High-Speed Direct Mask Fabrication Via Ultrasonic-Vibration-Assisted Mechanical Plowing, pp. 1784-1791.

Wang, Zhihua	Rutgers, the State Univ. of New Jersey

Zou, Qingze — Rutgers, the State Univ. of New Jersey

11:15-11:35 — WeAT3.4

Design of a Piezoelectric Poly-Actuated Linear Motor, pp. 1792-1801.

Tsukahara, Shinichiro — Sumitomo Heavy Industries, Ltd.
Penalver-Aguila, Lluis — Massachusetts Inst. of Tech.
Torres, James — Massachusetts Inst. of Tech.
Asada, H. Harry — Massachusetts Inst. of Tech.

11:35-11:55 — WeAT3.5

An Iterative Learning Controller for High Precision Calibration of an Inertial Measurement Unit Using a Piezoelectric Platform, pp. 1802-1808.

Edamana, Biju — Univ. of Michigan
Oldham, Kenn — Univ. of Michigan

11:55-12:15 — WeAT3.6

Static and Dynamic Modeling of a Multi-Axis Thin-Film Piezoelectric Micro-Actuator, pp. 1809-1817.

Choi, Jongsoo — Univ. of Michigan
Rhee, Choong-Ho — Univ. of Michigan, Ann Arbor
Qiu, Zhen — Univ. of Michigan
Wang, Thomas — Univ. of Michigan
Oldham, Kenn — Univ. of Michigan

WeAT4 — Paul Brest West

Flow and Thermal Systems (Contributed session)

Chair: Li, Yaoyu — Univ. of Texas at Dallas
Co-Chair: Ayalew, Beshah — Clemson Univ.

10:15-10:35 — WeAT4.1

Pod-Galerkin-Reduced Model Predictive Control for Radiative Drying of Coatings, pp. 1818-1826.

Cao, Xiaoqing — Clemson Univ.
Ayalew, Beshah — Clemson Univ.

10:35-10:55 — WeAT4.2

Reliable Sensing of Leaks in Pipelines, pp. 1827-1836.

Chatzigeorgiou, Dimitris — MIT
Wu, You — Massachusetts Inst. of Tech.
Youcef-Toumi, Kamal — Massachusetts Inst. of Tech.
Ben-Mansour, Rached — King Fahd Univ. of Petroleum & Minerals

10:55-11:15 — WeAT4.3

Polymer Flow Control in Continuous Gravimetric Blenders, pp. 1837-1844.

Cologni, Alberto Luigi — Univ. degli studi di Bergamo
Formentin, Simone — Univ. of Bergamo
Previdi, Fabio — Univ. degli Studi di Bergamo
Savaresi, Sergio Matteo — Pol. Di Milano

11:15-11:35 — WeAT4.4

Fast, High-Fidelity Simulation of Dynamic Thermo-Fluid States in Refrigeration Systems, pp. 1845-1853.

Wait, Keith — General Electric Appliances
Abbasi, Bahman — Booz Allen Hamilton
Kempiak, Michael — General Electric

11:35-11:55 — WeAT4.5

Spatio-Temporal Estimation of Wildfire Growth, pp. 1854-1861.

Sharma, Balaji — Univ. of Cincinnati
Kumar, Manish — Univ. of Toledo
Cohen, Kelly — Univ. of Cincinnati

11:55-12:15 — WeAT4.6

Comparison of Several Self-Optimizing Control Methods for Efficient Operation for a Chilled Water Plant, pp. 1862-1870.

Mu, Baojie — The Univ. of Texas at Dallas
Li, Yaoyu — Univ. of Texas at Dallas
Seem, John E. — Johnson Controls Inc.

WeAT5 — Tent B

Biologically-Inspired Control and Its Applications (Invited session)

Chair: Abaid, Nicole — Virginia Pol. Inst. and State Univ.
Co-Chair: Butail, Sachit — Pol. Inst. of New York Univ.
Organizer: Abaid, Nicole — Virginia Pol. Inst. and State Univ.
Organizer: Porfiri, Maurizio — Pol. Inst. of NYU

10:15-10:35 — WeAT5.1

Collective Response of Zebrafish to a Mobile Robotic Fish (I), pp. 1871-1878.

Butail, Sachit — Pol. Inst. of New York Univ.
Bartolini, Tiziana — NYU-Pol.
Porfiri, Maurizio — Pol. Inst. of NYU

10:35-10:55 — WeAT5.2

Bats versus Bugs: Collective Behavior of Prey Decreases Predation in a Biologically-Inspired Multi-Agent System (I), pp. 1879-1886.

Lin, Yuan — Virginia Pol. Inst. and State Univ.
Abaid, Nicole — Virginia Pol. Inst. and State Univ.

10:55-11:15 — WeAT5.3

Determining Human Control Intent Using Inverse LQR Solutions (I), pp. 1887-1894.

Priess, M. Cody — Michigan State Univ.
Choi, Jongeun — Michigan State Univ.
Radcliffe, Clark J. — Michigan State Univ.

11:15-11:35 — WeAT5.4

Bio-Inspired Nonholonomic Tracking Control (I), pp. 1895-1904.

Shoemaker, Adam — Virginia Tech.
Leonessa, Alexander — Virginia Tech.

11:35-11:55 — WeAT5.5

A Predictor-Compensator Design to Assist Human Decision-Making Process in an Air-Traffic-Control Simulator (I), pp. 1905-1913.

Sadeghzadeh, Keivan — Northeastern Univ.
Sipahi, Rifat — Northeastern Univ.

11:55-12:15 — WeAT5.6

Timoshenko Beam Model for Exploration and Sensing with a Continuum Centipede Inspired Robot (I), pp. 1914-1921.

Fattahi, S.Javad — Univ. of Ottawa
Spinello, Davide — Univ. of Ottawa

WeAT6 — Room 134

Beams and Flexible Structures (Contributed session)

Chair: Chalhoub, Nabil — Wayne State Univ.
Co-Chair: Jalili, Nader — Northeastern Univ.

10:15-10:35 — WeAT6.1

Effects of Non-Collocated Sensors and Actuators on the Controller of a Flexible Beam, pp. 1922-1928.

Mastory, Constantine — Wayne State Univ.

Chalhoub, Nabil — Wayne State Univ.

10:35-10:55 — WeAT6.2

Ultra Sensitive Piezoelectric-Based Microcantilever Sensor Operating at High Modes for Detection of Ultrasmall Masses, pp. 1929-1938.

Faegh, Samira — Northeastern Univ.
Jalili, Nader — Northeastern Univ.

10:55-11:15 — WeAT6.3

Derivatives and Parameter Designs of Arbitrary Cross-Section Inhomogenous Beams' Modes, pp. 1939-1945.

Xing, Jianwei — Tsinghua Univ.
Zheng, Gangtie — Tsinghua Univ.

11:15-11:35 — WeAT6.4

Free Vibration Analysis of a Beam with an Attached In-Span Beam with Tip Mass, pp. 1946-1953.

Oumar, Barry — Univ. of Toronto
Oguamanam, Donatus — Ryerson Univ.
Zu, Jean — Univ. of Toronto

11:35-11:55 — WeAT6.5

Modeling and Control of a Thermoelastic Beam, pp. 1954-1959.

Tuzcu, Ilhan — California State Univ. Sacramento
Gonzalez-Rocha, Javier — California State Univ. Sacramento

11:55-12:15 — WeAT6.6

Diagnostic Subspace Identification for the Dynamical Structural Models (I), pp. 1960-1967.

Almutawa, Jaafar — King Fahd Univ. of Petroleum and Minerals

WeAT7 — Room 138

Linear Systems and Robust Control (Contributed session)

Chair: Nersesov, Sergey G. — Villanova Univ.
Co-Chair: Duan, Chang — North Carolina State Univ.

10:15-10:35 — WeAT7.1

New Results on Continuous-Time Switched Linear Systems with Actuator Saturation, pp. 1968-1976.

Duan, Chang — North Carolina State Univ.
Wu, Fen — North Carolina State Univ.

10:35-10:55 — WeAT7.2

A Linear Matrix Inequality Solution to the Input Covariance Constraint Control Problem, pp. 1977-1983.

White, Andrew — Michigan State Univ.
Zhu, Guoming — Michigan State Univ.
Choi, Jongeun — Michigan State Univ.

10:55-11:15 — WeAT7.3

Robust Control of Switched Linear Systems Via Min of Quadratics, pp. 1984-1993.

Yuan, Chengzhi — North Carolina State Univ.
Wu, Fen — North Carolina State Univ.

11:15-11:35 — WeAT7.4

Output Reversibility in Linear Discrete-Time Dynamical Systems, pp. 1994-2001.

Nersesov, Sergey G. — Villanova Univ.
Deshmukh, Venkatesh — Villanova Univ.
Ghasemi, Masood — Villanova Univ.

11:35-11:55 — WeAT7.5

Asymptotic Properties of Zeros of Sampled-Data Systems for Continuous-Time Plants with Nondecouplability, pp. 2002-2006.

Ishitobi, Mitsuaki — Kumamoto Univ.
Kunimatsu, Sadaaki — Osaka Univ.

11:55-12:15 — WeAT7.6

A High Performance Tracking Control Method Based on a Disturbance Observer with Parameter Adaptation, pp. 2007-2015.

Hyun, Dong Jin — Massachusetts Inst. of Tech.
Choi, Jungsu — Sogang Univ.
Kong, Kyoungchul — Sogang Univ.

WeBT1 — Paul Brest East

Vehicle Path Planning and Collision Avoidance (Invited session)

Chair: Sadrpour, Amir — Univ. of Michigan
Co-Chair: Kolodziej, Jason — Rochester Inst. of Tech.
Organizer: Scacchioli, Annalisa — New York Univ.
Organizer: Kolodziej, Jason — Rochester Inst. of Tech.
Organizer: Canova, Marcello — The Ohio State Univ.
Organizer: Shahbakhti, Mahdi — Michigan Tech. Univ.
Organizer: Hall, Carrie — Purdue Univ.
Organizer: Yan, Fengjun — McMaster Univ.

13:30-13:50 — WeBT1.1

Guidance of a Robotic Off-Road Tractor-Trailer System Using Model Predictive Control (I), pp. 2016-2021.

Salmon, James — Auburn Univ.
Bevly, David — Auburn Univ.
Hung, John Y. — Auburn Univ.

13:50-14:10 — WeBT1.2

Real-Time Energy-Efficient Path Planning for Unmanned Ground Vehicles Using Mission Prior Knowledge (I), pp. 2022-2031.

Sadrpour, Amir — Univ. of Michigan
Ulsoy, A. Galip — Univ. of Michigan
Jin, Judy — Univ. of Michigan

14:10-14:30 — WeBT1.3

Simple Clothoid Paths for Autonomous Vehicle Lane Changes at the Limits of Handling (I), pp. 2032-2041.

Funke, Joseph — Stanford Univ.
Gerdes, J. Christian — Stanford Univ.

14:30-14:50 — WeBT1.4

Multi-Objective Collision Avoidance (I), pp. 2042-2051.

Ali, Mohammad — Volvo Car Corp.
Gray, Andrew — Univ. of California Berkeley
Gao, Yiqi — Univ. of California, Berkeley
Hedrick, Karl — Univ. of California at Berkeley
Borrelli, Francesco — UC Berkeley

14:50-15:10 — WeBT1.5

Determination of Minimum State Preview Time to Prevent Vehicle Rollover (I), pp. 2052-2059.

Stankiewicz, Paul — Penn State Univ.
Brown, Alexander — The Pennsylvania State Univ.
Brennan, Sean — Penn State Univ.

15:10-15:30 — WeBT1.6

Using a Path-Fitting Algorithm to Analyze the Racing Techniques of a Skilled Driver (I), pp. 2060-2066.

Samper-Mejia, Juan-Pablo — Stanford Univ.
Theodosis, Paul A. — Stanford Univ.

Gerdes, J. Christian	Stanford Univ.

WeBT2	Room 123
Robotics and Manipulators (Contributed session)	
Chair: Chen, Wenjie	Univ. of California at Berkeley
Co-Chair: Lee, Kok-Meng	Georgia Inst. of Tech.

13:30-13:50	WeBT2.1

Automatic Sensor Frame Identification in Industrial Robots with Joint Elasticity, pp. 2067-2075.

Lin, Chung-Yen	Univ. of California, Berkeley
Chen, Wenjie	Univ. of California at Berkeley
Tomizuka, Masayoshi	Univ. of California, Berkeley

13:50-14:10	WeBT2.2

Impedance Reduction Controller Design for Mechanical Systems, pp. 2076-2081.

Woo, Hanseung	Sogang Univ.
Kong, Kyoungchul	Sogang Univ.

14:10-14:30	WeBT2.3

Fast Modeling and Identification of Robot Dynamics Using the Lasso, pp. 2082-2085.

Wang, Cong	Univ. of California, Berkeley
Yu, Xiaowen	UC berkeley
Tomizuka, Masayoshi	Univ. of California, Berkeley

14:30-14:50	WeBT2.4

A Random Matrix Approach to Manipulator Jacobian, pp. 2086-2095.

Sovizi, Javad	Univ. at Buffalo
Alamdari, Aliakbar	Univ. at Buffalo
Krovi, Venkat N.	SUNY Buffalo

14:50-15:10	WeBT2.5

Dynamics Modeling and Identification of a Dual-Blade Wafer Handling Robot, pp. 2096-2102.

Yu, Xiaowen	UC berkeley
Wang, Cong	Univ. of California, Berkeley
Zhao, Yu	Tsinghua Univ.
Tomizuka, Masayoshi	Univ. of California, Berkeley

15:10-15:30	WeBT2.6

Discrete Deformation Models for Real-Time Computation of Compliant Mechanisms, pp. 2103-2111.

Ji, Jingjing	Zhejiang Univ.
Lee, Kok-Meng	Georgia Inst. of Tech.

WeBT3	Tent A
Sensing (Contributed session)	
Chair: Kim, Won-jong	Texas A&M Univ.
Co-Chair: Clayton, Garrett	Villanova Univ.

13:30-13:50	WeBT3.1

Spatial Feature Matching for Visual Odometry: A Parametric Study, pp. 2112-2118.

Clayton, Garrett	Villanova Univ.
Fabian, Joshua	Villanova Univ.

13:50-14:10	WeBT3.2

Visual Servoing for Robot Manipulators Considering Sensing and Dynamics Limitations, pp. 2119-2126.

Wang, Cong	Univ. of California, Berkeley
Lin, Chung-Yen	Univ. of California, Berkeley
Tomizuka, Masayoshi	Univ. of California, Berkeley

14:10-14:30	WeBT3.3

Vibration Measurement and Monitoring of a Rotating Disk Using Contactless Laser Excitation (I), pp. 2127-2131.

Kajiwara, Itsuro	Hokkaido Univ.
Hosoya, Naoki	Shibaura Inst. of Tech.

14:30-14:50	WeBT3.4

Robust State Estimation with Redundant Proprioceptive Sensors, pp. 2132-2141.

Rollinson, David	Carnegie Mellon Univ.
Choset, Howie	Carnegie Mellon Univ.
Tully, Stephen	Carnegie Mellon Univ.

14:50-15:10	WeBT3.5

A Human Motion Capture System Based on Inertial Sensing and a Complementary Filter, pp. 2142-2150.

Kanjanapas, Kan	Univ. of California at Berkeley
Wang, Yizhou	Univ. of California at Berkeley
Zhang, Wenlong	Univ. of California at Berkeley
Whittingham, Lauren	UC Berkeley
Tomizuka, Masayoshi	Univ. of California, Berkeley

15:10-15:30	WeBT3.6

A New Rotary Position-Control System with Color Sensing, pp. 2151-2159.

Kwon, Young-shin	Texas A&M Univ.
Kim, Won-jong	Texas A&M Univ.

WeBT4	Paul Brest West
Control of Mechanical Systems (Contributed session)	
Chair: Richer, Edmond	Southern Methodist Univ.
Co-Chair: Pagilla, Prabhakar R.	Oklahoma State Univ.

13:30-13:50	WeBT4.1

Modeling, Identification and Adaptive Robust Motion Control of Voice-Coil Motor Driven Stages, pp. 2160-2167.

Li, Chao	Zhejiang Univ.
Chen, Zheng	Dalhousie Univ.
Yao, Bin	Zhejiang Univ.
Wang, Qingfeng	Zhejiang Univ.

13:50-14:10	WeBT4.2

Hardening and Softening Characteristics of a Piecewise Linear Isolator under 1g Gravity, pp. 2168-2174.

Wang, Xing	Tsinghua Univ.
Zheng, Gangtie	Tsinghua Univ.

14:10-14:30	WeBT4.3

Decentralized Control of Print Registration in Roll-To-Roll Printing Presses, pp. 2175-2184.

Seshadri, Aravind	Oklahoma State Univ.
Pagilla, Prabhakar R.	Oklahoma State Univ.

14:30-14:50	WeBT4.4

Development of Energy Management Strategies for Heavy Mobile Machinery, pp. 2185-2192.

Lajunen, Antti	Aalto Univ.

14:50-15:10	WeBT4.5

A Validated System-Level Thermodynamic Model of a Reciprocating Compressor with Application to Valve Condition Monitoring, pp. 2193-2202.

Kolodziej, Jason — Rochester Inst. of Tech.
Guerra, Christopher — Dresser-Rand

15:10-15:30 — WeBT4.6

A Lumped-Parameter Model for Dynamic MR Damper Control, pp. 2203-2207.

Case, David — Southern Methodist Univ.
Taheri, Behzad — Southern Methodist Univ.
Richer, Edmond — Southern Methodist Univ.

WeBT5 — Tent B

System Identification and Modeling (Invited session)

Chair: Kfoury, Giscard — Lawrence Tech. Univ.
Co-Chair: Chalhoub, Nabil — Wayne State Univ.
Organizer: Kfoury, Giscard — Lawrence Tech. Univ.
Organizer: Chalhoub, Nabil — Wayne State Univ.

13:30-13:50 — WeBT5.1

Statistics Based Detection and Isolation of UEGO Sensor Faults (I), pp. 2208-2215.

Jammoussi, Hassene — Ford Motor Company
Makki, Imad — Ford Motor Company
Filev, Dimitar — Ford
Franchek, Matthew — Univ. of Houston

13:50-14:10 — WeBT5.2

An Ionic-Polymer-Metal-Composite Electrical Model with a Linear Time-Variant Method (I), pp. 2216-2223.

Chang, Yi-chu — Texas A&M Univ.
Kim, Won-jong — Texas A&M Univ.

14:10-14:30 — WeBT5.3

Nonlinear Models for Optimal Placement of Magnetically-Actuated Cilia (I), pp. 2224-2230.

Banka, Nathan — U. of Washington
Devasia, Santosh — Univ. of Washington

14:30-14:50 — WeBT5.4

Battery Health Diagnostics Using Retrospective-Cost Subsystem Identification: Sensitivity to Noise and Initialization Errors (I), pp. 2231-2240.

Zhou, Xin — Univ. of Michigan
Ersal, Tulga — Univ. of Michigan
Stein, Jeffrey L. — Univ. of Michigan
Bernstein, Dennis S. — Univ. of Michigan

14:50-15:10 — WeBT5.5

Structural Dynamic Imaging through Interfaces Using Piezoelectric Actuation and Laser Vibrometry for Diagnosing the Mechanical Properties of Composite Materials (I), pp. 2241-2250.

Watson, Christopher — Purdue Univ.
Adams, Douglas — Purdue Univ.
Rhoads, Jeffrey — Purdue Univ.

15:10-15:30 — WeBT5.6

Designing Network Motifs in Connected Vehicle Systems: Delay Effects and Stability (I), pp. 2251-2260.

Zhang, Linjun — Univ. of Michigan
Orosz, Gabor — Univ. of Michigan

WeBT6 — Room 134

Vibrational and Mechanical Systems (Contributed session)

Chair: Mahmoodi, Nima — The Univ. of Alabama
Co-Chair: Jalili, Nader — Northeastern Univ.

13:30-13:50 — WeBT6.1

Modeling the Effects of Heat Transfer Processes on Material Strain and Tension in Roll-To-Roll Manufacturing, pp. 2275-2282.

Lu, Youwei — Oklahoma State Univ.
Pagilla, Prabhakar R. — Oklahoma State Univ.

13:50-14:10 — WeBT6.2

Dynamic Modeling and Updating of a Stacked Plate Dynamic System, pp. 2267-2274.

Lundstrom, Troy — Northeastern Univ.
Sidoti, Charles — Northeastern Univ.
Jalili, Nader — Northeastern Univ.

14:10-14:30 — WeBT6.3

A Linearization-Based Approach to Vibrational Control of Second-Order Systems, pp. 2261-2266.

Wickramasinghe, Imiya — Texas Tech. Univ.
Berg, Jordan M. — Texas Tech. Univ.

14:30-14:50 — WeBT6.4

Dynamic Response of a Dual-Hoist Bridge Crane, pp. 2283-2290.

Maleki, Ehsan — Georgia Inst. of Tech.
Singhose, William — Georgia Inst. of Tech.
Vaughan, Joshua — Univ. of Louisiana at Lafayette
Hawke, Jeffrey — Georgia Inst. of Tech.

14:50-15:10 — WeBT6.5

Active Vibration Control of Resonant Systems Via Multivariable Modified Positive Position Feedback, pp. 2291-2298.

Omidi, Ehsan — The Univ. of Alabama
Mahmoodi, Nima — The Univ. of Alabama

15:10-15:30 — WeBT6.6

Relation between End-Effector Impedance and Joint Friction of Statically-Balanced Mechanisms, pp. 2299-2307.

Xiu, Wenwu — New Mexico State Univ.
Ma, Ou — New Mexico State Univ.

WeBT7 — Room 138

Fault Detection (Contributed session)

Chair: Gao, Robert — Univ. of Connecticut
Co-Chair: Ayalew, Beshah — Clemson Univ.

13:30-13:50 — WeBT7.1

Observer Based Fault Detection and Identification in Differential Algebraic Equations, pp. 2308-2317.

Scott, Jason R. — North Carolina State Univ. Department of Mathematics
Campbell, Stephen L — North Carolina State Univ.

13:50-14:10 — WeBT7.2

Diagnostics of a Nonlinear Pendulum Using Computational Intelligence, pp. 2318-2325.

Samadani, Mohsen — Department of Mechanical Engineering, Villanova Univ. PA
Kwuimy, Cedrick — VILLANOVA Univ. Mech Eng
Nataraj, 'Nat' C. — Villanova Univ.

14:10-14:30 — WeBT7.3

Fault Modelling for Hierarchical Fault Diagnosis and Prognosis, pp. 2326-2335.

Zhang, Jiyu — OSU
Rizzoni, Giorgio — Ohio State Univ.

Ahmed, Qadeer	CAR, OSU

14:30-14:50	WeBT7.4

Fault Diagnosis on a Digital-Displacement Pump/Motor, pp. 2336-2345.

Wang, Chunjian	Clemson Univ.
Ayalew, Beshah	Clemson Univ.
Filipi, Zoran	Clemson Univ.

14:50-15:10	WeBT7.5

An Experimentally Validated Model for Reciprocating Compressor Main Bearings with Application to Health Monitoring, pp. 2346-2354.

Holzenkamp, Markus	Rochester Inst. of Tech.
Kolodziej, Jason	Rochester Inst. of Tech.
Boedo, Stephen	Rochester Inst. of Tech.
Delmotte, Scott	Dresser-Rand Company

15:10-15:30	WeBT7.6

Failure Detection and Trend Prediction of Rolling Element Bearing Based on Approximate Entropy, pp. 2355-2361.

Wang, Peng	Univ. of Connecticut
Gao, Robert	Univ. of Connecticut
Huaqing, Wang	Beijing Univ. of Chemical Tech.
Yuan, Hongfang	Beijing Univ. of Chemical Tech.

Technical Program for Monday October 21, 2013

MoAT1	Paul Brest East
Control of Advanced Combustion Engines (Invited session)	
Chair: Shahbakhti, Mahdi	Michigan Tech. Univ.
Co-Chair: Hall, Carrie	Purdue Univ.
Organizer: Shahbakhti, Mahdi	Michigan Tech. Univ.
Organizer: Hall, Carrie	Purdue Univ.
Organizer: Canova, Marcello	The Ohio State Univ.
Organizer: Scacchioli, Annalisa	New York Univ.
Organizer: Yan, Fengjun	McMaster Univ.
Organizer: Kolodziej, Jason	Rochester Inst. of Tech.

10:15-10:35 MoAT1.1

LPV Control of an Electronic Throttle (I), pp. 1-7

Zhang, Shupeng	Michigan State Univ.
White, Andrew	Michigan State Univ.
Yang, Jie	Shanghai Jiaotong Univ.
Zhu, Guoming	Michigan State Univ.

In this paper, a discrete-time electronic throttle model was developed based upon the parameters obtained through system identification. To design gain-scheduling controllers using LPV (linear parameter varying) scheme, the throttle was modeled as an LPV system, where the vehicle battery voltage and the non-linear friction coefficient are the measurable time-varying parameters. Gain-scheduling controller was designed for the LPV throttle system using the linear matrix inequality (LMI) convex optimization approach. The designed controller is validated through simulations and show that the proposed controller provides improved performance over the baseline fixed gain controller.

10:35-10:55 MoAT1.2

Closed-Loop Control of SI-HCCI Mode Switch Using Fuel Injection Timing (I), pp. 8-16

Ravi, Nikhil	Robert Bosch Res. and Tech. Center
Jagsch, Michael	Univ.
Oudart, Joël	Robert Bosch Res. and Tech. Center
Chaturvedi, Nalin A.	Robert Bosch LLC
Cook, David	Robert Bosch Res. and Tech. Center
Kojic, Aleksandar	Robert Bosch Res. and Tech. Center North America

Homogeneous charge compression ignition (HCCI) provides improved efficiency and emissions relative to current engine technologies. One of the barriers to implementing HCCI on production engines is the development of a robust control strategy to transition from traditional spark-ignition (SI) mode to HCCI mode and back. This paper presents such a strategy, based on the control of combustion phasing using fuel injection timing during the mode switch from SI to HCCI. The controller is based on a cycle-by-cycle combustion model developed in previous work. In order to obtain a state estimator for both modes, the model is linearized around operating points corresponding to the steady-states before (SI) and after (HCCI) the switch. The linearized HCCI model is used to synthesize a closed-loop controller to track a desired combustion phasing, with fuel injection timing as the controlled input. The control strategy is tested on a single-cylinder HCCI engine with direct injection. Experimental results at different operating points show that the controller is able to maintain a desirable phasing transient during the mode switch, prevent cycles with very early or late phasing and enable smooth transitions with minimal load fluctuations.

10:55-11:15 MoAT1.3

Design of Automotive Control Systems Robust to Hardware Imprecision (I), pp. 17-23

Edelberg, Kyle	UC Berkeley
Pan, Selina	Univ. of California, Berkeley
Hedrick, Karl	Univ. of California at Berkeley

The hardware used for software implementation on a physical system introduces uncertainty into the controller. If neglected during design, this uncertainty can lead to poor controller performance, resulting in significant design and verification iterations. In this work, the effect of sampling time, quantization, and fixed-point computation are directly accounted for in the control design. Sampling time is compensated for by a discrete-time controller. A generic methodology is developed for modeling the worst-case scenario effect of quantization and fixed-point computation on the control commands. The cold-start emission control problem is used as a case study, and a discrete-time sliding surface controller is developed. Verification is performed to ensure the estimated worst-case scenario uncertainty bounds are accurate. The bounds are incorporated into a modified version of the control laws. During simulation the modified controller demonstrates significant reduction in tracking error in the presence of hardware imprecisions.

11:15-11:35 MoAT1.4

Flatness-Based Control of Mode Transitions between Conventional and Premixed Charge Compression Ignition on a Modern Diesel Engine with Variable Valve Actuation (I), pp. 24-33

Hall, Carrie	Purdue Univ.
Van Alstine, Daniel	Purdue Univ.
Shaver, Gregory M.	Purdue Univ.

Energy needs in the transportation sector and strict emissions regulations have caused a growing focus on increasing engine efficiency while simultaneously minimizing engine out emissions. One method for accomplishing this is to leverage advanced combustion strategies which are efficient yet very clean. One such combustion mode is premixed charge compression ignition (PCCI). PCCI can lead to drastically lower emissions than conventional diesel combustion while still maintaining engine efficiencies; however, the engine operation region over which it can be utilized is limited. In order to take advantage of this advanced combustion mode, engines must be designed to move between conventional diesel combustion and PCCI. To achieve transitions between different combustion modes, a control strategy was developed which utilizes a extensively validated gas exchange model and flatness-based methods for trajectory planning and trajectory tracking to enable smooth transitions between different combustion modes on a modern diesel engine with variable valve actuation. Since the engine considered here has the ability to alter valve timings, the control method exploits both capabilities to control the gas exchange process as well as the effective compression ratio of the engine. Simulation results indicate that this flatness-based approach is effective in enabling mode transitions.

11:35-11:55 MoAT1.5

Rate Shaping Estimation and Control of a Piezoelectric Fuel Injector (I), pp. 34-41

Le, Dat	Purdue Univ.
Pietrzak, Bradley	Purdue Univ.
Shaver, Gregory M.	Purdue Univ.

Fuel injection rate shaping is one way to improve fuel efficiency and reduce harmful emissions in IC engines. Piezoelectrically actuated fuel injectors have a particularly fast response, which makes them capable of rate shaping operation. In this paper, a model-based

closed-loop controller is designed to control the fuel injection rate passing through the nozzle of a piezoelectric fuel injector, by compensating for the injector's nonlinear behavior. The performance of this controller is verified with simulation results.

11:55-12:15	MoAT1.6

Transient Control of a Hydraulic Free Piston Engine (I), pp. 42-47

Li, Ke	Univ. of Minnesota-Twin Cities
Zhang, Chen	Univ. of Minnesota
Sun, Zongxuan	Univ. of Minnesota

The free piston engine (FPE) is a type of internal combustion engine (ICE) with no crankshaft, so that its piston motion is no longer constrained by mechanical linkages. The FPE has a high potential in terms of energy saving given its simple structure, high modularity and high efficiency. One of the technical barriers that prevents the wide spread of the FPE technology, is the lack of precise piston motion control. Previously, a robust repetitive controller is designed and implemented to form a virtual crankshaft that would provide a precise and stable engine operation. The experimental data of engine motoring tests with virtual crankshaft demonstrates the effectiveness of the controller. However, the presence of a transient period after a single combustion event prevents the engine from continuous firing. This paper presents a modified control scheme, which utilizes a reference and control signal shifting technique to modify the tracking error and the control signal to reduce the transient period.

MoAT2	Room 123
Bipeds and Locomotion (Contributed session)	
Chair: Wu, Christine Qiong	Univ. of Manitoba
Co-Chair: Mukherjee, Ranjan	Michigan State Univ.

10:15-10:35	MoAT2.1

Energy-Conserving Gaits for Point-Foot Planar Bipeds: A Five-Dof Case Study, pp. 48-55

Jafari, Rouhollah	Michigan State Univ.
Flynn, Louis	Michigan State Univ.
Hellum, Aren	NUWC Newport
Mukherjee, Ranjan	Michigan State Univ.

We propose a general method for designing energy conserving gaits for point-foot planar bipeds. The method relies on satisfying specific boundary conditions for joint trajectories of the biped. These boundary conditions ensure that potential and kinetic energies of the biped are the same at the beginning and end of each step and there is no impact, i.e, no energy loss, at the time of swing-foot touchdown. The mechanical energy required by the gait over each step is therefore zero from the principle of work and energy. To illustrate the procedure for designing energy-conserving gaits, the proposed method is applied to a general five-dof biped.

10:35-10:55	MoAT2.2

Smoothly Transitioning between Ballistic and Corrective Control to Produce Human-Like Movement, pp. 56-64

Shelton, Jeff	Purdue Univ.
Mynderse, James A.	Lawrence Tech. Univ.
Chiu, George T.-C.	Purdue Univ.

Human reaching movement appears to consist of an initial ballistic segment that drives the hand toward the target, then a corrective segment that brings the hand into the target region. This article discusses how the motions produced by two different controllers, one guiding the ballistic portion and one directing the corrective potion, can be merged into a single smooth movement that is reminiscent of human reaching. Simulated movements based on the proposed methodology are shown to be consistent with human kinematic trajectories.

10:55-11:15	MoAT2.3

Simulation and Prediction of the Motion of a Human in a Vertical Jumping Task, pp. 65-73

Hariri, Mahdiar	Univ. of Iowa
Xiang, Yujiang	Univ. of Iowa
Chung, Hyun-Joon	Univ. of Iowa
Bhatt, Rajan	Univ. of Iowa
Arora, Jasbir	Univ. of Iowa
Abdel-Malek, Karim	Univ. of Iowa

In this work, we offer an optimization based motion prediction of a vertical jumping task for a human. The human model has 55 degrees of freedom. This is a multi-objective optimization problem where the mechanical energy and discomfort are minimized at the same time and an additional motion capture tracking objective function is used to have a more natural motion, specially for less determinant degrees of freedom in the jumping task. The problem is subject to all the Newtonian motion constraints such as ZMP constraint while on the ground and projectile motion constraints for a dynamic system (6 independent constraints that determine the changes in the net linear and angular momentum of the system) while off the ground. In this simulation the height of jump can either be specified by the user or maximized by the optimization module. This simulation is able to predict both the kinematic and dynamic effects of different inputs on the motion where kinematic effects refer to changes in the motion and dynamic effects refer to changes in forces and torques. Different inputs consist of but are not limited to: changes in the human size, mass, strength properties, changes in the mass and inertia of the equipments attached to the human and changes in the height of jump (for specified height jumps).

11:15-11:35	MoAT2.4

Development of an Advanced Model of Passive Dynamic Biped Walking, pp. 74-83

Koop, Derek Oliver	Univ. of Manitoba
Wu, Christine Qiong	Univ. of Manitoba

Passive dynamic walking is a manner of walking developed, partially or in whole, by the energy provided by gravity. Studying passive dynamic walking provides insight into human walking and is an invaluable tool for designing energy efficient biped robots. The objective of this research was to develop a continuous mathematical model of passive dynamic walking, in which the Hunt-Crossley contact model and the LuGre friction model were used to represent the normal and tangential ground reactions. A physical passive walker was built to validate the proposed mathematical model. A traditional impact-based passive walking model was also used as a reference to demonstrate the advancement of the proposed passive dynamic walking model. The simulated gait of the proposed model matched the gait of the physical passive walker exceptionally well, both in trend and magnitude.

11:35-11:55	MoAT2.5

Investigation of the Suitability of Utilizing Permutation Entropy to Characterize Gait Dynamics, pp. 84-88

Leverick, Graham	Univ. of Manitoba
Szturm, Tony	School of Medical Rehabilitation, Univ. of Manitoba
Wu, Christine Qiong	Univ. of Manitoba

Permutation entropy (PE) is a natural measure of the complexity of a dynamic system which boasts robustness to noise and computational efficiency. Since its introduction in 2002, PE has served as a valuable tool for assessing nonlinear systems such as speech signals and EEG signals. In this paper, the suitability of utilizing PE as a new method for characterizing walking gait dynamics is explored. Results obtained by analyzing the medial-lateral center of pressure migration of participants during treadmill walking demonstrate that PE shows good preliminary repeatability. PE shows sensitivity to a change in walking conditions; walk alone vs. addition of a concurrent cognitive task. A highly significant age effect in PE ($p<0.001$) during dual task walking was observed. Further analysis revealed no significant age effect on PE for the walk alone condition.

11:55-12:15	MoAT2.6

Inertially Actuated Baton Locomotor, pp. 89-97

Zoghzoghy, Joe	Southern Methodist Univ.
Alshorman, Ahmad	SMU
Hurmuzlu, Yildirim	SMU

In this paper, we present a robotic locomotor with inertiabased actuation. The goal of this system is to generate various gait modes of a baton, consisting of two masses connected with a massless rod. First, a model for a baton prototype called Pony I is presented. This model incorporates the inertial forces generated by a rotating single pendulum. The model also accounts for the friction forces that arise in the contact points of the baton with the ground surface. We also developed an experimental prototype for a baton with a single-pendulum actuator. Consequently, we compared the nonlinear dynamics of the analytical and experimental systems. An improved double-pendulum actuation system was proposed for better regulation of the locomotion of the system and the orientation of the centrifugal force. Finally, demonstrated that this system generated steady forward locomotion.

MoAT3	Tent A

Aerial Vehicles (Contributed session)

Chair: Siciliano, Bruno	Univ. degli Studi di Napoli Federico II
Co-Chair: Ray, Asok	Pennsylvania State Univ.

10:15-10:35	MoAT3.1

Exploiting Image Moments for Aerial Manipulation Control, pp. 98-107

Mebarki, Rafik	PRISMA Lab. Univ. degli Studi di Napoli Federico II
Lippiello, Vincenzo	Univ. of Naples Federico II
Siciliano, Bruno	Univ. degli Studi di Napoli Federico II

This paper proposes a new visual servo control scheme that endows flying manipulators with the capability of positioning with respect to visual targets. A camera attached to the UAV provides real-time images of the scene. We consider the approaching part of an aerial assembling task, where the manipulator carries a structure to be plugged into the visual target. In order to augment the system capabilities regarding the 3D interaction with the target, we propose to use image moments. The developed controller generates desired velocities to both the UAV and the manipulator, simultaneously. While taking into account the under-actuation specific to rotary-wing vehicles, it makes use of the system redundancy to realize potential sub-tasks. The joints limits avoidance is also guaranteed. The presented developments are validated by means of computer simulations.

10:35-10:55	MoAT3.2

Identification of Instabilities in Rotorcraft Systems, pp. 108-112

Sonti, Siddharth	Pennsylvania State Univ. Univ. Park, PA
Eric, Keller	Pennsylvania State Univ. Univ. Park, PA
Horn, Joseph	The Pennsylvania State Univ.
Ray, Asok	Pennsylvania State Univ.

This short paper presents a data-driven method for identification of stability margin in rotorcraft system dynamics and the underlying concept is built upon the principles of Symbolic Dynamics. The algorithm involves wavelet-packet-based preprocessing to remove spurious disturbances and to improve the signal-to-noise ratio (SNR) of the sensor time series. A quantified measure, called Instability Measure, is constructed from the processed time series data to obtain an estimate of the relative instability of the dynamic modes of interest on the rotorcraft system. The proposed method has been tested with numerical simulations and correlations between the Instability Measure and the damping parameters of selected dynamic modes of the rotor blade have been established.

10:55-11:15	MoAT3.3

Dynamic Modeling and Simulation of a Remote-Controlled Helicopter with a Suspended Load, pp. 113-118

Potter, James Jackson	Georgia Inst. of Tech.
Simpson, Ryan	Georgia Inst. of Tech.
Singhose, William	Georgia Inst. of Tech.

A helicopter testbed has been constructed to study the dynamic effects of loads suspended below the helicopter by cables. A dynamic model of the helicopter-load system is presented, as well as a procedure to estimate the unknown model parameters. The simulated helicopter is controlled by a virtual pilot with attributes that are scaled to match the model helicopter's fast dynamics. Initial simulations show that the presence of a heavy load makes it difficult to maintain a steady hover position after a horizontal movement.

11:15-11:35	MoAT3.4

Enhanced Proportional-Derivative Control of a Micro Quadcopter, pp. 119-123

Johnson, Norman L.	Univ. of Nevada, Reno
Leang, Kam K.	Univ. of Nevada, Reno

This paper studies the design of an enhanced proportional derivative (PD) controller to improve the transient response of a micro quadrotor helicopter (quadcopter). In particular, the controller minimizes the effect of disturbances by considering the orientation and rotation of the platform. A dynamics model is developed for an experimental micro quadcopter platform, and simulation results are presented that compare the proposed enhanced PD controller to a standard PD controller. Results show a 50% reduction in the peak response and a 45%reduction in the settling time, demonstrating the effectiveness of the controller.

11:35-11:55	MoAT3.5

Proportional Navigation (pn) Based Tracking of Ground Targets by Quadrotor Uavs, pp. 124-133

Tan, Ruoyu	Univ. of Cincinnati
Kumar, Manish	Univ. of Toledo

This paper addresses the problem of controlling a rotary wing Unmanned Aerial Vehicle (UAV) tracking a target moving on ground. The target tracking problem by UAVs has received much attention recently and several techniques have been developed in literature most of which have been applied to fixed wing aircrafts. The use of quadrotor UAVs, the subject of this paper, for target tracking presents several challenges especially for highly maneuvering targets since the development of time-optimal controller (required if target is maneuvering fast) for quadrotor UAVs is extremely difficult due to highly non-linear dynamics. The primary contribution of this paper is the development of a proportional navigation (PN) based method and its implementation on quad-rotor UAVs to track moving ground target. The PN techniques are known to be time-optimal in nature and have been used in literature for developing guidance systems for missiles. There are several types of guidance laws that come within the broad umbrella of the PN method. The paper compares the performance of these guidance laws for their application on quadrotors and chooses the one that performs the best. Furthermore, to apply this method for target tracking instead of the traditional objective of target interception, a switching strategy has also been designed. The method has been compared with respect to the commonly used Proportional Derivative (PD) method for target tracking. The experiments and numerical simulations performed using maneuvering targets show that the proposed tracking method not only carries out effective tracking but also results into smaller oscillations and errors when compared to the widely used PD tracking method.

11:55-12:15	MoAT3.6

*A Van Der Pol Oscillator Model for Lift Force Produced by Heaving NACA-0012 Airfoil at Low Reynolds Number**

Khalid, Muhammad Saif Ullah	National Univ. of Sciences & Tech.
Akhtar, Imran	National Univ. of Sciences & Tech.

MoAT4	Paul Brest West
Wind Energy Systems and Control (Invited session)	
Chair: Vermillion, Christopher	Altaeros Energies
Co-Chair: Chen, Dongmei	The Univ. of Texas at Austin
Organizer: Vermillion, Christopher	Altaeros Energies
Organizer: Chen, Dongmei	The Univ. of Texas at Austin

10:15-10:35 MoAT4.1

Altitude and Crosswind Motion Control for Optimal Power-Point Tracking in Tethered Wind Energy Systems with Airborne Power Generation (I), pp. 134-142

Vermillion, Christopher	Altaeros Energies

This paper presents a control strategy that combines altitude and crosswind motion control for tethered wind energy systems with airborne turbines and generators. The proposed algorithm adjusts altitude and induces an appropriate level of crosswind motion to present the system with an apparent wind speed that most closely meets, but does not exceed, the rated wind speed of the on-board turbine(s), thereby tracking the turbine's optimal power point. The adjustment of both altitude and crosswind motion, along with the reduction in altitude and crosswind motion when the rated wind speed is exceeded, differentiates the proposed control architecture from other strategies proposed in the literature. Initial control laws and simulation results are presented for the Altaeros lighter-than-air wind energy system.

10:35-10:55 MoAT4.2

Optimal Control of a Wind Turbine for Tradeoff Analysis between Energy Harvesting and Noise Emission (I), pp. 143-147

Shaltout, Mohamed	Univ. of Texas at Austin
Chen, Dongmei	The Univ. of Texas at Austin

An optimal control approach for a wind turbine drivetrain with the objective of maximizing energy harvesting and minimizing noise emission is presented. One of the major challenges facing the public acceptance for continuous growth of wind turbine installation is its noise emission. However, reducing the noise emission could lead to decreased wind energy harvesting. As a result, a tradeoff arises between power generation and noise emission, especially when a wind turbine operates under the partial-load condition. This paper will show that through controlling the generator electromagnetic torque and/or the blade pitch angle, an optimal tradeoff between wind turbine energy harvesting and noise emission can be obtained. The dynamic model of a wind turbine drivetrain and a noise emission prediction model are also presented. Simulation results of using the proposed control design for different wind speed ranges are analyzed and compared.

10:55-11:15 MoAT4.3

An Application of the Autogyro Theory to Airborne Wind Energy Extraction (I), pp. 148-155

Rimkus, Sigitas	Univ. of Central Florida
Das, Tuhin	Univ. of Central Florida

Auto-rotation or autogyro is a well-known phenomenon where a rotor in a wind field generates significant lift while the wind induces considerable aerodynamic torque on the rotor. The principle has been studied extensively for applications in aviation. However, with recent works indicating immense, persistent, and pervasive, available wind energy at high altitudes, the principle of autogyro could potentially be exploited for energy harvesting. In this paper, we carry out a preliminary investigation on the viability of using autogyros for energy extraction. We mainly focus on one of the earliest documented works on modeling of autogyro and extend its use to explore energy harvesting. The model is based on blade element theory. We provide simulation results of the concept. Although the results are encouraging, there are various practical aspects that need to be investigated to build confidence on this approach of energy harvesting. This work aims to build a framework upon which more comprehensive research can be conducted.

11:15-11:35 MoAT4.4

Active Control of Wind Turbine Rotor Torsional Vibration (I), pp. 156-163

White, Warren N.	Kansas State Univ.
Yu, Zhichao	Kansas State Univ.
Miller, Ruth Douglas	Kansas StateUniversity
Ochs, David	Kansas State Univ.

Transient and harmonic stresses in wind turbine rotor shafts contribute to gearbox failure. This paper investigates the reduction of rotor shaft torsional vibrations through active control of the generator torque. A 5 MW turbine model is used to test the procedure. A model of a permanent magnet synchronous generator is included as part of the wind turbine simulation. The simulations are carried out using the software FAST from the National Renewable Energy Laboratory (NREL). The PI and feedback linearized controller for the generator is derived together with the means for vibration isolation. Examples of steady, time varying, and turbulent wind are presented which all show significant reduction in the torsional oscillations.

11:35-11:55 MoAT4.5

Maximizing Wind Farm Energy Capture Via Nested-Loop Extremum Seeking Control (I), pp. 164-171

Yang, Zhongzhou	Univ. of Wisconsin-Milwaukee
Li, Yaoyu	Univ. of Texas at Dallas
Seem, John E.	Johnson Controls Inc.

This paper proposes a novel control approach for optimizing wind farm energy capture with a nested-loop scheme of extremum seeking control (ESC). Similar to Bellman's Principle of Optimality, it has been shown in earlier work that the axial induction factors of individual wind turbines can be optimized from downstream to upstream units in a sequential manner,i.e. the turbine operation can be optimized based on the power of the immediate turbine and its downstream units. In this study, this scheme is illustrated for wind turbine array with variable-speed turbines for which torque gain is controlled to vary axial induction factors. The proposed nested-loop ESC is demonstrated with a 3-turbine wind farm using the SimWindFarm simulation platform. Simulation under smooth and turbulent winds shows the effectiveness of the proposed scheme. Analysis shows that the optimal torque gain of each turbine in a cascade of turbines is invariant with wind speed if the wind direction does not change, which is supported by simulation results for smooth wind inputs. As changes of upstream turbine operation affects the downstream turbines with significant delays due to wind propagation, a cross-covariance based delay estimate is proposed as adaptive phase compensation between the dither and demodulation signals.

11:55-12:15 MoAT4.6

Nonlinear Controller Design with Bandwidth Consideration for a Novel Compressed Air Energy Storage System (I), pp. 172-179

Saadat, Mohsen	Univ. of Minnesota
Shirazi, Farzad	Univ. of Minnesota- Postdoctoral Res. Associate
Li, Perry Y.	Univ. of Minnesota

Maintaining the accumulator pressure regardless of its energy level and tracking the power demanded by the electrical grid are two potential advantages of the Compressed Air Energy Storage (CAES) system proposed in the previous works. In order to achieve these goals, a nonlinear controller is designed based on an energy-based Lyapunov function. The control inputs of the storage system include displacement of the pump/motor in the hydraulic transformer and displacement of the liquid piston air compressor/expander. While the latter has a relatively low bandwidth, the former is a faster actuator with a higher bandwidth. In addition, the pneumatic path of the storage vessel that is connected to the liquid piston air compressor/expander has a high energy density, whereas the hydraulic path of the storage vessel is power dense. The nonlinear controller is then modified to achieve a better performance for the entire system according to these properties. In the proposed approach, the control effort is distributed between the two pump/motors based on their bandwidths: the hydraulic transformer reacts to high frequency events, while the liquid piston air compressor/expander performs a steady storage/regeneration task. As a result, the liquid piston air compressor/expander will loosely maintain the accumulator pressure ratio and the pump/motor in the hydraulic transformer will precisely track the desired generator power. This control scheme also allows the accumulator to function as a damper in the storage system by absorbing power disturbances from the hydraulic path generated by wind gusts.

MoAT5	Tent B
Dynamical Modeling and Diagnostics in Biomedical Systems (Invited session)	
Chair: Ghorbanian, Parham	Villanova Univ.
Co-Chair: Jalali, Ali	Villanova Univ.
Organizer: Ghorbanian, Parham	Villanova Univ.
Organizer: Jalali, Ali	Villanova Univ.
Organizer: Nataraj, C.	Villanova Univ.
Organizer: Ashrafiuon, Hashem	Villanova Univ.

10:15-10:35	MoAT5.1

State Dynamics of the Epileptic Brain (I), pp. 180-186

Burns, Samnuel	Johns Hopkins Univ.
Santaniello, Sabato	Johns Hopkins Univ.
Anderson, William	Johns Hopkins Hospital
Sarma, Sridevi V.	Johns Hopkins Univ.

Communication between specialized regions of the brain is a dynamic process allowing for different connections to accomplish different tasks. While the content of interregional communication is complex, the pattern of connectivity (i.e., which regions communicate) may lie in a lower dimensional state-space. In epilepsy, seizures elicit changes in connectivity, whose patterns shed insight into the nature of seizures and the seizure focus. We investigated connectivity in 3 patients by applying network-based analysis on multi-day subdural electrocorticographic recordings (ECoG). We found that (i) the network connectivity defines a finite set of brain states, (ii) seizures are characterized by a consistent progression of states, and (iii) the focus is isolated from surrounding regions at the seizure onset and becomes most connected in the network towards seizure termination. Our results suggest that a finite-dimensional state-space model may characterize the dynamics of the epileptic brain, and may ultimately be used to localize seizure foci.

10:35-10:55	MoAT5.2

Modeling and System Identification of Hemodynamic Responses to Vasopressor-Inotropes (I), pp. 187-195

Bighamian, Ramin	Univ. of Maryland
Soleymani, Sadaf	Univ. of Southern California
Reisner, Andrew	Harvard Medical School
Seri, Istvan	Children's Hospital Los Angeles
Hahn, Jin-Oh	Univ. of Maryland

In an effort to establish an initial step towards the ultimate goal of developing an analytic tool to optimize the vasopressor-inotrope therapy through individualized dose-response relationships, we propose a phenomenological model intended to reproduce the hemodynamic response to vasopressor-intoropes. The proposed model consists of a cardiovascular model relating blood pressure to cardinal cardiovascular parameters (stroke volume and total peripheral resistance) and the phenomenological relationships between the cardinal cardiovascular parameters and the vasopressor-intorope dose, in such a way that the model can be adapted to individual patient solely based upon blood pressure and heart rate responses to medication dosing. In this paper, the preliminary validity of the proposed model is shown using the experimental epinephrine dose versus blood pressure and heart rate response data collected from five newborn piglets. Its performance and potential usefulness are discussed. It is anticipated that, potentially, the proposed phenomenological model may offer a meaningful first step towards the automated control of vasopressor-inotrope therapy.

10:55-11:15	MoAT5.3

Stochastic Dynamic Modeling of the Human Brain EEG Signal (I), pp. 196-201

Ghorbanian, Parham	Villanova Univ.
Ramakrishnan, Subramanian	Villanova Univ.
Simon, Adam	Cerora, Inc.
Ashrafiuon, Hashem	Villanova Univ.

The occurrence and risk of recurrence of brain related injuries and diseases are difficult to characterize due to various factors including inter-individual variability. A useful approach is to analyze the brain electroencephalogram (EEG) for differences in brain frequency bands in the signals obtained from potentially injured and healthy normal subjects. However, significant shortcomings include: (1) contrary to empirical evidence, current spectral signal analysis based methods often assume that the EEG signal is linear and stationary; (2) nonlinear time series analysis methods are mostly numerical and do not possess any predictive features. In this work, we develop models based on stochastic differential equations that can output signals with similar frequency and magnitude characteristics of the brain EEG. Initially, a coupled linear oscillator model with a large number of degrees of freedom is developed and shown to capture the characteristics of the EEG signal in the major brain frequency bands. Then, a nonlinear stochastic model based on the Duffing oscillator with far fewer degrees of freedom is developed and shown to produce outputs that can closely match the EEG signal. It is shown that such a compact nonlinear model can provide better insight into EEG dynamics through only few parameters, which is a step towards developing a framework with predictive capabilities for addressing brain injuries.

11:15-11:35	MoAT5.4

Classification of Postural Response in Parkinson's Patients Using Support Vector Machines (I), pp. 202-209

Shukla, Amit	Miami Univ.
Mani, Ashutosh	Univ. of Cincinnati
Bhattacharya, Amit	Univ. of Cincinnati
Revilla, Fredy	Univ. of Cincinnati

Parkinson's disease (PD) is a neurodegenerative condition with neuronal cell death in the substantia nigra and striatal dopamine deficiency that produces slowness, stiffness, tremor, shuffling gait and postural instability. More than 1 million people in North America are affected by PD resulting in balance problems and falls. It is observed that postural instability and gait problems become resistant to pharmacologic therapy as the disease progresses. Furthermore, studies suggest that postural sway abnormalities are worsened by Levodopa, the mainstay of therapy for PD. This paper presents a classification of postural balance test data using Support Vector Machines (SVM) to identify the effect of medicine (levodopa) as well as dyskinesia. It is demonstrated that SVM is a useful tool and can complement the widely accepted (but very resource intensive) Unified

Parkinson's Disease Rating Scale (UPDRS).

11:35-11:55	MoAT5.5

Theoretical Development and Experimental Validation of an Adaptive Controller for Tremor Suppression at Musculoskeletal Level, pp. 210-217

Taheri, Behzad	Southern Methodist Univ.
Case, David	Southern Methodist Univ.
Richer, Edmond	Southern Methodist Univ.

Tremor is a rhythmical and involuntary oscillatory movement of a body part. Mechanical loading via wearable exoskeletons is a non-invasive tremor suppression alternative to medical treatments. In this approach, the challenge is attenuating the tremor without affecting the patient's intentional motion. An adaptive tremor suppression algorithm was designed to estimate and restrict motion within the tremor frequency band. An experimental setup was designed and developed to simulate the dynamics of a human arm joint with intentional and tremorous motion. The required orthotic suppressive force was applied via a pneumatic cylinder. The algorithm was implemented with a real-time controller and experimental results show tracking of the tremor frequency and a $97%$ reduction of tremor amplitude at the fundamental frequency.

11:55-12:15	MoAT5.6

A Method of Swing Leg Control for a Minimally Actuated Medical Exoskeleton for Individuals with Paralysis, pp. 218-226

Reid, Jason I.	Univ. of California, Berkeley
McKinley, Michael G.	Univ. of California
Tung, Wayne Yi-Wei	Univ. of California, Berkeley
Pillai, Minerva Vasudevan	Univ. of California, Berkeley
Kazerooni, Homayoon	Univ. of California at Berkeley

This paper discusses the control of a medical exoskeleton swing leg that has a “passive” (unactuated) knee. Previous work in legged locomotion has demonstrated the feasibility of achieving natural, energy efficient walking with minimally actuated robotic systems. This work will present early results for a medical exoskeleton that only has actuation that powers the flexion and extension of the biological hip. In this work, a hybrid model of the state dependent kinematics and dynamics of the swing leg will be developed and parameterized to yield swing hip dynamics as a function of desired knee flexion dynamics. This model is used to design swing hip motions that control the flexion behavior of the passive swing knee in a human-like manner. This concept was tested by a paraplegic user wearing a new minimally actuated exoskeleton. The presented results show that a human-like swing phase can be achieved with an exoskeleton that has fewer actuated degrees of freedom than current medical exoskeletons.

MoAT6	Room 134

Control, Monitoring, and Energy Harvesting of Vibratory Systems: Active Vibration Control -1 (Invited session)

Chair: Zuo, Lei	Stony Brook Univ. - SUNY
Co-Chair: Kajiwara, Itsuro	Hokkaido Univ.
Organizer: Zuo, Lei	Stony Brook Univ. - SUNY
Organizer: Tang, Jiong	Univ. of Connecticut
Organizer: Sipahi, Rifat	Northeastern Univ.
Organizer: Caruntu, Dumitru	Univ. of Texas Pan American
Organizer: Nishimura, Hidekazu	Keio Univ.
Organizer: Kajiwara, Itsuro	Hokkaido Univ.

10:15-10:35	MoAT6.1

Bridge Life Extension Using Semi-Active Vibration Control (I), pp. 227-235

Nelson, Garrett	Univ. of Minnesota
Rajamani, Rajesh	Univ. of Minnesota
Gastineau, Andrew	Univ. of Minnesota
Schultz, Arturo	Univ. of Minnesota
Wojtkiewicz, Steve	Univ. of Minnesota

The fatigue life of a bridge can be extended by fifty years just by reducing the peak strain levels it experiences by 33%.This paper utilizes a dynamic model of the Cedar Avenue tied arch steel bridge in Minnesota to investigate active control technologies for peak strain reduction. Simulations show that the use of passive structural modification devices such as stiffeners and dampers is inadequate to reduce the key resonant peaks in the frequency response of the bridge. Both active and semi-active vibration control strategies are then pursued. Active vibration control can effectively reduce all resonant peaks of interest, but is practically difficult to implement on a bridge due to power, size, and cost considerations. Semi-active control with a variable orifice damper in which the damping coefficient is changed in real-time using bridge vibration feedback can be practically implemented. Simulation results show that the proposed semi-active control system can reduce many of the resonant peaks of interest, but is unable to reduce the response at one key resonant frequency. Further analysis reveals that the location of the actuator on the bridge chosen for the semi-active controller is inappropriate for controlling the specific resonant frequency of issue. By modifying the actuator location, it would be possible to obtain control of all bridge resonant frequencies with the semi-active control system.

10:35-10:55	MoAT6.2

Development of Nonlinear Control Algorithms for Shaking Table Tests (I), pp. 236-243

Yang, T.Y.	Univ. of British Columbia
Li, Kang	National Taiwan Univ.
Lin, Jian Yuan	National Taiwan Univ.
Li, Yuanjie	Univ. of British Columbia

Shaking table testing method is one of the main sources of experimental means to evaluate the dynamic response of structural systems under earthquake loads. The experimental technique produces nearly realistic prototype conditions, giving important insight into critical issues such as collapse mechanisms, component failures, acceleration amplifications, residual displacements and post-earthquake capacities. Traditional tuning of shaking table relies on the use of linear controllers, which are designed to regulate linear systems. With most of the specimens being tested to highly nonlinear states (to understand the structural response under extreme loads), traditional linear controllers can no longer control the shaking table effectively. This results in experimental errors between commanded and measured shaking table movements which may produce an unintended response of the tested structure. Ultimately, it may result in a pre-mature failure of the specimen. To address this issue, a Lyapunov–based nonlinear control algorithm is utilized to develop an enhanced shaking table control system, which is based on nonlinear models accounting for the nonlinear response of the hydraulic actuator and specimens. A one-sixth-scaled model has been developed and constructed in the laboratory at the University of British Columbia, Vancouver. Advanced nonlinear system identification techniques have been developed to create the numerical model capable of recreating the nonlinearity experienced by the laboratory setup. Simulation results indicate that the developed nonlinear control algorithm can be used to achieve excellent tracking, even when the tested structure behaves nonlinearly. The example also demonstrates the ability of the nonlinear controller to compensate for disturbances in the actuating force applied to the shaking table. Thus, the proposed nonlinear shaking table control algorithm is not only a viable alternative, but also a way to significantly improve the quality of shaking table tests.

10:55-11:15	MoAT6.3

Regenerative Vibration Control of Tall Buildings Using Model Predictive Control (I), pp. 244-253

Liu, Yilun	State Univ. of New York at Stony

Brook

Zuo, Lei — Stony Brook Univ. - SUNY

Tang, Xiudong — Stony Brook Univ.

The regenerative Tuned Mass Damper (TMD) can convert the vibration energy of the tall building into the electricity, by replacing the damping element with electromagnetic harvester. The energy harvesting circuit therein which can regulate the electricity and control the vibration will introduce some constraints when designing vibration controller. This paper designed the vibration controller based on Model Predictive control (MPC). The control force constraints were taken into consideration before designing the controller. The building model with semi-active constraints due to the regenerative properties of the TMD is converted into a Mixed Logical Dynamical (MLD) system first. Then the optimal controller is designed by solving the Mixed Integer Quadratic Programming (MIQP) problem. The results were evaluated and compared to the ones using “clipped-optimal” controller with the same constraints. It is found that the MPC controller can provide the same or better vibration control Results depending on the predicted horizon. Besides, an explicit MPC is obtained to reduce the online computation effort.

11:15-11:35 — MoAT6.4

Active Vibration Control Based on Self-Sensing for Unkown Target Structures by Direct Velocity Feedback with Adaptive Feed-Forward Cancellation (I), pp. 254-258

Yabui,, Shota — Hokkaido Univ.

Kajiwara, Itsuro — Hokkaido Univ.

Ookita, Ryohei — Hokkaido Univ. Div. of Human Mechanical\\ Systems and

This paper presents active vibration control based on self-sensing for unknown target structures by direct velocity feedback (DVFB) with enhanced adaptive feed-forward cancellation (AFC). AFC is known as an adaptive control method, and the adaptive algorithm can estimate a periodic disturbance. In a previous study, an enhanced AFC was developed to compensate for a non-periodic disturbance. An active vibration control based on self-sensing by DVFB can suppress mechanical resonance by using relative velocity between the voice coil actuator and a target structure. In this study, the enhanced AFC was applied to compensate disturbance for the self-sensing vibration control system. The simulation results showed the vibration control system with DVFB and enhanced AFC could suppress mechanical resonance and compensate disturbances.

11:35-11:55 — MoAT6.5

Closed Loop Fusion Technique for the Shaking Table Motion Control (I), pp. 259-264

Shimono, Keisuke — Tokyo Univ. of Agriculture and Tech.

Tagawa, Yasutaka — Tokyo Univ. of Agriculture and Tech.

Shaking tables are frequently used for dynamical testing. To produce correct results, a shaking table must be able to move according to the desired acceleration signal in a wide range of frequencies. Accelerometers and displacement sensors are used for controlling input, and, in some cases, they have been used for preventing drift. However, at low frequencies, accelerometers do not always provide accurate values. We developed a shaking-table control system that uses a sensor-fusion control function. In this paper, we present the design scheme for our control system and the results of a simulation that validate it.

11:55-12:15 — MoAT6.6

Simulation Based Control and Its Application to a Crane System (I), pp. 265-274

Tagawa, Yasutaka — Tokyo Univ. of Agriculture and Tech.

Shimono, Keisuke — Tokyo Univ. of Agriculture and Tech.

In this paper, at first, a basic concept of IDCS (Inverse Dynamics Compensation via ‘Simulation of feedback control'), which is based on feedback simulation, is introduced. Then, it is demonstrated that inverse dynamics of the non-linear system is easily calculated by IDCS. In the latter half of the article, IDCS is applied to a control problem of a crane system with varying wire length. The purpose of the control system is to move a load of the crane system as fast as possible without unnecessary vibration. Several control simulations and experiments are conducted, then the effectiveness of the control system is confirmed..

MoAT7 — Room 138

Delay Systems (Contributed session)

Chair: Sipahi, Rifat — Northeastern Univ.

Co-Chair: Ersal, Tulga — Univ. of Michigan

10:15-10:35 — MoAT7.1

Graph Laplacian Design for Fast Consensus of a {LTI} System with Heterogeneous Agent Couplings and Homogeneous Inter-Agent Delays, pp. 275-282

Qiao, Wei — Northeastern Univ.

Atay, Fatihcan — Max Planck Inst. for Mathematics in the Sciences

Sipahi, Rifat — Northeastern Univ.

A class of LTI consensus network dynamics with heterogeneous agent coupling strengths and homogeneous inter-agent delays is under investigation. An approach to design the graph Laplacian of the system is developed here for achieving fast consensus, departing from the analytical study of the rightmost eigenvalue behavior of this dynamics. Detailed design procedure is presented with a demonstrative example.

10:35-10:55 — MoAT7.2

Equivalency of Stability Transitions between the Sds (spectral Delay Space) and Ds (delay Space), pp. 283-291

Gao, Qingbin — Univ. of Connnecticut

Zalluhoglu, Umut — Univ. of Connecticut

Olgac, Nejat — Univ. of Connecticut

It has been shown that the stability of LTI time-delayed systems with respect to the delays can be analyzed in two equivalent domains: (i) delay space (DS) and (ii) spectral delay space (SDS). Considering a broad class of linear time-invariant time delay systems with multiple delays, the equivalency of the stability transitions along the transition boundaries is studied in both spaces. For this we follow two corresponding radial lines in DS and SDS, and prove for the first time in literature that they are equivalent. This property enables us to extract local stability transition features within the SDS without going back to the DS. The main advantage of remaining in SDS is that, one can avoid a non-linear transition from kernel hypercurves to offspring hypercurves in DS. Instead the potential stability switching curves in SDS are generated simply by stacking a finite dimensional cube called the building block (BB) along the axes. A case study is presented within the report to visualize this property.

10:55-11:15 — MoAT7.3

A Comparison of the Simulated Dynamics of Various Models Used to Predict Undeformed Chip Thickness in High-Speed Low-Radial-Immersion Milling Processes, pp. 292-298

Bryan, Josiah — Univ. of Missouri

Fales, Roger — Univ. of Missouri-Columbia

Various models have been proposed to estimate the undeformed thickness of chips produced by a CNC milling tool, in order to calculate the forces acting on the tool. The choice of model significantly affects the simulated dynamics of the tool, thereby affecting the dynamic stability of the simulated process and whether or not chatter occurs in a given cutting scenario. Simulations of the dynamics of the milling process can be used to determine the conditions at which chatter occurs, which can lead to poor surface finish and tool damage. The dynamics of a traditional model and a more detailed numerical model are simulated here with particular emphasis on the differences in their chatter bifurcation points. High-speed, low-radial-immersion milling processes are simulated because of their application in industrial high-precision machining.

11:15-11:35	MoAT7.4

Design and Stability Analysis of Delayed Resonator with Acceleration Feedback, pp. 299-308

Vyhlidal, Tomas	Faculty of Mechanical Engineering, Czech Tech. Univ. in
Olgac, Nejat	Univ. of Connecticut
Kucera, Vladimir	Faculty of Mechanical Engineering, Czech Tech. Univ. in

This paper deals with the problem of active vibration suppression using the concept of delayed resonator with acceleration feedback. A complete dynamics analysis of the resonator and its coupling with a single degree of freedom mechanical system are performed. It is shown that due to presence of a delay in the derivative feedback, the dynamics of the resonator itself, as well as the dynamics of its coupling with the system are of neutral character. Subsequently, the spectral approach is used to obtain the stability boundaries in the space of the resonator parameters. Both, analytical and numerical methods are employed in the analysis. As the contributions, we display a methodology to determine the resonator parameters in order to guarantee desirable functioning of the resonator and to provide safe stability margins. An example is included to demonstrate these analytical results.

11:35-11:55	MoAT7.5

An Observer Based Framework to Improve Fidelity in Internet-Distributed Hardware-In-The-Loop Simulations, pp. 309-317

Tandon, Akshar	Univ. of Michigan
Brudnak, Mark	The US Army Tank-Automotive Res. Development andEngineering
Stein, Jeffrey L.	Univ. of Michigan
Ersal, Tulga	Univ. of Michigan

Co-simulating distributed hardware-in-the-loop systems in real time over the Internet entails communication delays that can lead to significant loss of fidelity and even instability in the system. To address this challenge, this paper proposes an observer based framework that, unlike previously reported efforts, does not require the observer to know and model the observed system dynamics. This is achieved by deriving the closed-loop dynamics of the observer based on a sliding surface. Even though the resulting error system does not necessarily stay on a sliding surface, its asymptotic convergence to zero is still guaranteed. First, this idea is developed for a generic networked system simulation framework and its stability is established. Then, it is applied to a mass-spring-damper system to illustrate the mechanics of the approach on a simple, linear example and demonstrate that the approach can stabilize the system that is otherwise unstable due to delay. Finally, a vehicle-engine-driver system simulation is considered to evaluate the performance of the approach on a more realistic, nonlinear example. An improvement of up to 33% is observed in the fidelity of the simulation. The conclusion is that the approach holds a significant potential to alleviate the negative impact of delay and improve the stability and fidelity of networked system simulations. Its benefits become more pronounced as the delay increases.

11:55-12:15	MoAT7.6

Preserving Stability under Communication Delays in Multi Agent Systems, pp. 318-327

Rastgoftar, Hossein	Univ. of Central Florida
Jayasuriya, Suhada	Univ. of Central Florida

The effect of time delays on the stability of a recently proposed continuum approach for controlling a multi agent system (MAS) evolving in n-D under a special local inter-agent communication protocol is considered. There, a homogenous map determined by n+1 leaders is learned by the follower agents each communicating with n+1 adjacent agents. In this work both position and velocity information of adjacent agents are used for local control of follower agents whereas in previous work [1, 2] only position information of adjacent agents was used. Stability of the proposed method under a time delay h is studied using the cluster treatment of characteristic roots (CTCR) [3]. It is shown that the stability of MAS evolution can be preserved when (i) the velocity of any follower agent is updated using both position and velocity of its adjacent agents at time (t-h); and (ii) the communication matrix has real eigenvalues. In addition, it is shown that when there is no communication delay, deviations from a selected homogenous map during transients may be minimized by updating only the position of a follower using both position and velocity of its adjacent agents.

MoBT1	Paul Brest East

Control Design Methods for Advanced Powertrain Systems and Components (Invited session)

Chair: Shahbakhti, Mahdi	Michigan Tech. Univ.
Co-Chair: Shaver, Gregory M.	Purdue Univ.
Organizer: Canova, Marcello	The Ohio State Univ.
Organizer: Scacchioli, Annalisa	New York Univ.
Organizer: Yan, Fengjun	McMaster Univ.
Organizer: Hall, Carrie	Purdue Univ.
Organizer: Kolodziej, Jason	Rochester Inst. of Tech.
Organizer: Shahbakhti, Mahdi	Michigan Tech. Univ.

13:30-13:50	MoBT1.1

Control Design for Cancellation of Unnatural Reaction Torque and Vibrations in Variable-Gear-Ratio Steering System (I), pp. 328-337

Oshima, Atsushi	NSK Ltd
Chen, Xu	Univ. of California, Berkeley
Sugita, Sumio	NSK Ltd
Tomizuka, Masayoshi	Univ. of California, Berkeley

Variable-gear-ratio steering is an advanced feature found in automotive vehicles. As the name suggest, it changes the steering gear ratio depending on the speed of the vehicle. This feature can simplify steering for the driver, which leads to various advantages, such as improved vehicle comfort, stability, and safety. One serious problem, however, is that the variable-gear-ratio system generates unnatural torque to the driver whenever the variable-gear-ratio control is activated. Such unnatural torque includes both low-frequency and steering-speed-dependent components. This paper proposes a control method to cancel this unnatural torque. We address the problem by using a tire sensor and a set of feedback and feedforward algorithms. Effectiveness of the proposed method is experimentally verified using a hardware-in-the-loop experimental setup. Stability and robustness under model uncertainties are evaluated.

13:50-14:10	MoBT1.2

Torque Phase Shift Control Based on Clutch Torque Estimation (I), pp. 338-345

Yanakiev, Diana	Ford Motor Company
Fujii, Yuji	Ford Motor Company
Tseng, Eric	Ford Motor Company
Pietron, Gregory M.	Ford Motor Co
Kucharski, Joseph F.	Ford Motor Co.
Kapas, Nimrod	Ford Motor Co

An automatic transmission shift method is presented, in which the torque transfer phase is controlled in closed loop. This is made possible by real-time estimation of the torque transmitted by the off-going and on-coming clutches participating in the shift. Each clutch torque is determined based on measured or estimated input and output shaft torques and accelerations. To illustrate an application of the method, traditional friction elements are used to emulate one-way-clutch function during a power-on upshift.

14:10-14:30 MoBT1.3

Investigation on the Energy Management Strategy for Hydraulic Hybrid Wheel Loaders (I), pp. 346-355

Wang, Feng — Univ. of Minnesota
Mohd Zulkefli, Mohd Azrin — Univ. of Minnesota
Sun, Zongxuan — Univ. of Minnesota
Stelson, Kim A. — Univ. of Minnesota

Energy management strategies for a hydraulic hybrid wheel loader are studied in this paper. The architecture of the hydraulic hybrid wheel loader is first presented and the differences of the powertrain and the energy management system between on-road vehicles and wheel loaders are identified. Unlike the on-road vehicles where the engine only powers the drivetrain, the engine in a wheel loader powers both the drivetrain and the working hydraulic system. In a non-hybrid wheel loader, the two sub-systems interfere with each other since they share the same engine shaft. By using a power split drivetrain, it not only allows for optimal engine operation and regenerative braking, but also eliminates interferences between driving and working functions, which improve the productivity, fuel efficiency and operability of the wheel loader. An energy management strategy (EMS) based on dynamic programming (DP) is designed to optimize the operation of both the power split drivetrain and the working hydraulic system. A short loading cycle is selected as the duty cycle. The EMS based on DP is compared with a rule-based strategy through simulation.

14:30-14:50 MoBT1.4

Design, Modeling and Control of a Novel Architecture for Automatic Transmissions (I), pp. 356-364

Mallela, Virinchi — Univ. of Minnesota - Twin Cities
Sun, Zongxuan — Univ. of Minnesota

Automotive transmissions are required to efficiently transfer power from the engine to the wheels. Automatic transmissions are one of the most widely used transmission systems. This transmission houses a hydraulic system that is used to actuate the clutch system to realize different gear ratios. Currently, these clutches are primarily controlled in open-loop using many valves in a complex control architecture designed specifically for a given transmission system in order to perform precise pressure and flow control. To meet the increasing demand for higher fuel economy, transmissions with greater number of gear ratios are being introduced. The hydraulic architecture is becoming increasingly complicated with more clutches and control elements. With the advancement of MEMS technology, the sensor-based direct feedback control of clutches becomes possible. This paper first analyzes the current architecture of transmission hydraulic actuation and then presents a new architecture for the feedback based clutches. The proposed architecture is further validated through experiments using a hardware-in-the-loop system.

14:50-15:10 MoBT1.5

Observer Based Oxygen Fraction Estimation for a Dual-Loop EGR Diesel Engine Fueled with Biodiesel Blends (I), pp. 365-371

Zhao, Junfeng — The Ohio State Univ.
Wang, Junmin — The Ohio State Univ.

This paper investigates the influence of biodiesel on the effectiveness of exhaust gas recirculation (EGR) in modern Diesel engines equipped with dual-loop EGR systems. Intake manifold oxygen fraction, which is an important factor for both combustion and emissions, is selected as a new reference for evaluating the equivalent EGR level instead of EGR ratio. A Luenberger-like observer for the oxygen fraction is designed based on the dynamic model of the air-path loop with consideration of the existence of oxygen content in the fuel. The convergence of the observer is proved with the assistance of some physical insight into the engine system. The performance of the observer is validated on a high-fidelity engine model built in GT-Power. The results show that when the same amount of fuel is injected, there is an increase in the exhaust oxygen concentration for biodiesel as oxygen content in fuel increases. Then the higher exhaust oxygen concentration leads to an increase in the intake manifold oxygen fraction, since the engine control unit (ECU) commanded EGR valve angles are constant across different fuels. This real-time oxygen fraction estimation approach is potentially useful for mitigating the biodiesel NOx emission effect.

15:10-15:30 MoBT1.6

A Dual-Loop EGR Engine Air-Path Oxygen Concentration Model with Time-Varying Transport Delays (I), pp. 372-378

Zeng, Xiangrui — The Ohio State Univ.
Wang, Junmin — The Ohio State Univ.

Dual-loop exhaust gas recirculation (EGR) systems can provide control authorities for adjusting the engine in-cylinder gas conditions. However, the transport delay in the EGR air-path makes some simple oxygen concentration dynamic models perform poorly under the transient operating conditions. In this paper, a dual-loop EGR air-path oxygen concentration model considering the time-varying transport delays is developed and a method to calculate the delay time based on the continuity of gas velocity is presented. Simulation validations using a high-fidelity GT-Power 1-D computational engine model show that the developed model can capture the oxygen concentration dynamics during both steady-state and transient operations.

MoBT2 Room 123

Human Assistive Systems and Wearable Robots: Applications and Assessment (Invited session)

Chair: Ueda, Jun — Georgia Inst. of Tech.
Co-Chair: Deshpande, Ashish — Univ. of Texas
Organizer: Ueda, Jun — Georgia Inst. of Tech.
Organizer: Deshpande, Ashish — Univ. of Texas

13:30-13:50 MoBT2.1

Body-Segment Orientation Estimation in Rider-Bicycle Interactions with an Un-Calibrated Monocular Camera and Wearable Gyroscopes (I), pp. 379-388

Lu, Xiang — Rutgers Univ.
Zhang, Yizhai — Rutgers Univ.
Yu, Kaiyan — Rutgers Univ.
Yi, Jingang — Rutgers Univ.
Liu, Jingtai — Nankai Univ.

We present a real-time human body-segment (e.g., upper limbs) orientation estimation scheme in rider-bicycle interactions. The estimation scheme is built on the fusion of measurements of an un-calibrated monocular camera on the bicycle and a set of small wearable gyroscopes attached to rider's upper limbs. The known optical features are conveniently collocated with the gyroscopes. The design of an extended Kalman filter (EKF) to fuse the vision/inertial measurements compensates for the drifting errors by directly integrating gyroscope measurements. The characteristic and constraints from human anatomy and the rider-bicycle interactions are used to enhance the EKF performance. We demonstrate the effectiveness of the estimation design through bicycle riding experiments. The attractive properties of the proposed pose estimation in human-machine interactions include low-cost, high-accuracy, and wearable configurations for outdoor personal activities. Although we only present the application for rider-bicycle interactions, the proposed estimation scheme is readily extended and

used for other types of human-machine interactions.

13:50-14:10	MoBT2.2

Interaction Control of a Non-Backdriveable MR-Compatible Actuator through Series Elasticity (I), pp. 389-398

Sergi, Fabrizio — Rice Univ.
Chawda, Vinay — Rice Univ.
O'Malley, Marcia — Rice Univ.

This research aims at developing a magnetic resonance (MR)-compatible equivalent of an exoskeleton used for wrist movement rehabilitation therapy of neurological patients. As a crucial step towards the accomplishment of this goal, this paper investigates the development of a novel actuation architecture suitable for interaction control in MR environments, the MR-SEA (SEA stands for Series Elastic Actuator). MR-SEA consists of the combination of a non-backdriveable MR-compatible actuator and of a compliant force-sensing element. The preliminary design of a 1 DOF actuator is presented, in addition to nonlinear dynamical model of the system featuring the most relevant actuator non linearities. A switching controller is proposed, and the asymptotic stability of the resulting discontinuous dynamical system is demonstrated for force control in blocked output conditions. Simulation results show that the proposed system is adequate for the implementation of force control for wrist movement protocols in fMRI, demonstrating a bandwidth higher than 8 Hz for force control. For stiffness control, simulation results demonstrate that the system is passive for all values of desired virtual stiffness lower than the stiffness of the physical spring, and isolated stability is obtained for the entire range of stiffness values considered.

14:10-14:30	MoBT2.3

Kinematic Analysis of Virtual Reality Task Intensity Induced by a Rehabilitation Robotic System in Stroke Patients (I), pp. 399-406

Simkins, Matt — UC Santa Cruz
Roldan, Jay Ryan — Univ. of California Santa Cruz
Kim, Hyunchul — Apple Inc
Abrams, Gary — Univ. of California, San Francisco
Byl, Nancy — Univ. of California San Francisco
Rosen, Jacob — Univ. of California - Santa Cruz

Robotic systems provide a paradigm shift in maximizing neural plasticity as part of human motor control recovery following stroke. Such a system shifts the treatment from therapist dependent to patient dependent by its potential to increase the treatment dose, as long as the patient can tolerate it. The experimental protocol included 10 post stroke hemiparetic subjects in a chronic stage. Subjects were treated with an exoskeleton system (EXO-UL7) using a unilateral mode, and a bilateral mode. Seven virtual reality tasks were utilized in the protocol. A kinematic-based methodology was used to study the intensity of the virtual reality task in each one of the operational modes. The proposed method is well suited for early evaluation of a given virtual reality task, or movement assistance modality during the development process. Pilot study data were analyzed using the proposed methodology. This allowed for the identification of kinetic differences between the assistance modalities by assessing the intensity of the virtual reality tasks.

14:30-14:50	MoBT2.4

Control of Voluntary and Involuntary Nerve Impulses for Hemiparesis Rehabilitation and MRI Study (I), pp. 407-414

Lacey, Lauren — Georgia Inst. of Tech.
Buharin, Vasiliy — Georgia Inst. of Tech.
Turkseven, Melih — Georgia Inst. of Tech.
Shinohara, Minoru — Georgia Inst. of Tech.
Ueda, Jun — Georgia Inst. of Tech.

In order for stroke victims to gain functional recovery of their hemiparetic limbs, facilitation techniques such as the repetitive facilitation exercise, or RFE, have been developed. Currently, there is a lack of understanding of the neural mechanisms associated with these types of facilitation techniques. To better understand the neural mechanisms associated with the RFE a functional magnetic resonance imaging (fMRI) study should be conducted. This paper presents initial experimental results testing the feasibility of implementing an fMRI-compatible actuator to facilitate a myotatic reflex in synchronization with the patient's intention to move the hemiparetic limb. Preliminary data from a healthy individual demonstrated the feasibility of overlapping the long latency component of the afferent myotatic reflex with descending nerve impulses in a time window of 15ms. In addition, to implement the RFE into an fMRI-compatible device, a pneumatic actuation time delay due to long transmission line was evaluated. The results may be used for the assessment of the RFE using an fMRI-compatible robotic device in the future.

14:50-15:10	MoBT2.5

Interaction Control for Rehabilitation Robotics Via a Low-Cost Force Sensing Handle (I), pp. 415-419

Erwin, Andrew — Rice Univ.
Sergi, Fabrizio — Rice Univ.
Chawda, Vinay — Rice Univ.
O'Malley, Marcia — Rice Univ.

This paper investigates the possibility of implementing force-feedback controllers using measurement of interaction force obtained through force-sensing resistors (FSRs), to improve performance of human interacting robots. A custom sensorized handle was developed, with the capability of simultaneously measuring grip force and interaction force during robot-aided rehabilitation therapy. Experiments are performed in order to assess the suitability of FSRs to implement force-feedback interaction controllers. In the force-feedback control condition, the applied force for constant speed motion of a linear 1DOF haptic interface is reduced 6.1 times compared to the uncontrolled condition, thus demonstrating the possibility of improving transparency through force-feedback via FSRs.

15:10-15:30	MoBT2.6

Control and Coordination of Supernumerary Robotic Limbs Based on Human Motion Detection and Task Petri Net Model (I), pp. 420-426

Llorens-Bonilla, Baldin — Massachusetts Inst. of Tech.
Asada, H. Harry — Massachusetts Inst. of Tech.

This paper presents a task model and communication method used to control and coordinate a wearable robot, termed Supernumerary Robotic Limb (SRL), with a human worker during the execution of a specialized task. When controlling a collaborative system like this, we need strong communication between the robot and its wearer in order to be able to coordinate their actions. We address the communication challenges between the human worker and the SRL by monitoring the worker's actions with wearable sensors. Combining these wearable sensors together with a well defined task model allows the robot to act according to the wearer's intent. The task model is structured using Coloured Petri Nets (CPN) due to the process' deterministic and concurrent nature. We performed various tests in which the user had to execute a task while wearing the sensor suit. This data was used to establish the threshold values for our predetermined gestures and postures of interest. Detecting these postures and gestures are used to trigger task transitions in the CPN model. This allows the wearer to communicate his intentions effectively to the SRL and execute the task in a well-structured and coordinated manner with the SRL.

MoBT3	Tent A
Aerospace Control (Contributed session)	
Chair: Sun, Jing	Univ. of Michigan
Co-Chair: Leang, Kam K.	Univ. of Nevada, Reno

13:30-13:50	MoBT3.1

Model Predictive Control of Spacecraft Relative Motion Maneuvers Using the IPA-SQP Approach, pp. 427-435

Park, Hyeongjun	Univ. of Michigan
Kolmanovsky, Ilya	The Univ. of Michigan, Ann Arbor
Sun, Jing	Univ. of Michigan

In this paper, a Model Predictive Controller (MPC) based on the Integrated Perturbation Analysis and Sequential Quadratic Programming (IPA-SQP) is designed and analyzed for spacecraft relative motion maneuvering. To evaluate the effectiveness of the IPA-SQP MPC, the results are compared with the linear quadratic MPC algorithm. It is shown that the IPA-SQP algorithm can handle directly nonlinear constraints on thrust magnitude without resorting to saturation or polyhedral norm approximations. Spacecraft fuel consumption related metrics are examined for performance evaluation and comparison.

13:50-14:10 MoBT3.2

Adaptive Control with Convex Saturation Constraints, pp. 436-445

Yan, Jin	Univ. of Michigan
Santos, Davi Antônio	Inst. Tecnológico de Aeronáutica
Bernstein, Dennis S.	Univ. of Michigan

This paper applies retrospective cost adaptive control (RCAC) to command following in the presence of multivariable convex input saturation constraints. To account for the saturation constraint, we use convex optimization to minimize the quadratic retrospective cost function. The use of convex optimization bounds the magnitude of the retrospectively optimized input and thereby influences the controller update to satisfy the control bounds. This technique is applied to a tiltrotor with constraints on the total thrust magnitude and inclination of the rotor plane.

14:10-14:30 MoBT3.3

Geometric Mechanics Based Modeling of the Attitude Dynamics and Control of Spacecraft with Variable Speed Control Moment Gyroscopes, pp. 446-455

Viswanathan, Sasi Prabhakaran	New Mexico State Univ.
Sanyal, Amit	New Mexico State Univ.
Leve, Frederick	Air Force Res. Lab. Space Vehicles Directorate
McClamroch, N. Harris	Univ. of Michigan

The attitude dynamics of a spacecraft with a variable speed control moment gyroscope (VSCMG), in the presence of external torques and internal inputs, is derived using variational principles. A complete dynamics model, that relaxes some of the assumptions made in prior literature on control moment gyroscopes, is obtained. A non-standard VSCMG model, that has an offset between the center of the gimbal axis and the center of the rotor (flywheel) is considered. The dynamics equations show the complex nonlinear coupling between the internal degrees of freedom associated with the VSCMG and the spacecraft base body's attitude degrees of freedom. Some of this coupling is induced by the non-zero offset between the gimbal axis and the rotor center. This dynamics model is then generalized to include the effects of multiple control moment gyroscopes placed in the base body with non-parallel gimbal axes. It is shown that the dynamical coupling can improve the control authority on the angular momentum of the base body of the spacecraft using changes in the momentum variables of the VSCMG. Numerical simulations confirm the use of these VSCMGs for attitude control for a given de-tumbling maneuver.

14:30-14:50 MoBT3.4

QUATERNION BASED MODEL FOR 6-DoF VEHICLES WITH APPLICATION TO a LOW EARTH ORBITER (I), pp. 456-462

Cepeda-Gomez, Rudy	Univ. Santo Tomas

In this paper an alternative model based on quaternions for the translational and attitude dynamics of a 6DoF vehicle is presented. Specifically, the properties of unit quaternions, well suited to embody rotations in three-dimensional spaces, are used for representing the most important modes related with attitude dynamics, while full quaternions, that allow the representation of rotations and magnifications at the same time, are used for the modeling of the translational dynamics. Simulation results are also included, as an application of the proposed approach to the control of a Low Earth Orbiter.

14:50-15:10 MoBT3.5

A Nonlinear Observer Design for a Rigid Body in the Proximity of a Spherical Asteroid, pp. 463-469

Izadi, Maziar	New Mexico State Univ.
Bohn, Jan	New Mexico State Univ.
Lee, Daero	New Mexico State Univ.
Sanyal, Amit	New Mexico State Univ.
Butcher, Eric	New Mexico State Univ.
Scheeres, Daniel	The Univ. of Colorado

We consider an observer design for a spacecraft modeled as a rigid body in the proximity of an asteroid. The nonlinear observer is constructed on the nonlinear state space of motion of a rigid body, which is the tangent bundle of the Lie group of rigid body motions in three-dimensional Euclidean space. The framework of geometric mechanics is used for the observer design. States of motion of the spacecraft are estimated based on state measurements. In addition, the observer designed can also estimate the gravity parameter of the asteroid, assuming the asteroid to have a spherically symmetric mass distribution. Almost global convergence of state estimates and gravity parameter estimate to their corresponding true values is demonstrated analytically, and verified numerically.

15:10-15:30 MoBT3.6

Applications of Slider Chain Inversion in Control Actuation Systems, pp. 470-476

Hasturk, Ozgur	Roketsan Missile Industries Inc.

Slider crank mechanism is usually used if the precise transfer of the rotation to the translation is required. Although,it has smooth operation, it is known that more efficient mechanism are available especially in petrol and diesel engines.

It is reported that Scotch yoke mechanism and inverted slider crank mechanism, equivalent to the slider crank mechanism in kinematically; have smoother operation and higher efficiency as compared to slider crank mechanism.

In this paper, inversion of the double slider crank chain and slider crank chain, Scotch yoke and inverted slider crank are compared in terms of their performance under identical geometrical constraints and discussed the possible use in control actuation systems.

MoBT4 Paul Brest West

Alternative Energy (Contributed session)

Chair: Madani, Omid	Univ. of Central Florida
Co-Chair: Li, Yaoyu	Univ. of Texas at Dallas

13:30-13:50 MoBT4.1

Transient Control in Multivariable Systems: A Study Motivated by Fuel Cells, pp. 477-485

Madani, Omid	Univ. of Central Florida
Das, Tuhin	Univ. of Central Florida

Controlling the transient response of variables for which sensing or accurate estimation is not feasible, and a detailed plant model is also largely unavailable, poses significant challenges. It is a situation that is true in solid oxide fuel cells. In SOFCs, transient control is essential for fuel utilization, especially if the fuel cell is to be operated in a dynamic load-following mode at high fuel utilization. The objective is to design the control input(s) such that it isolates the output (fuel utilization in this case) from measurable disturbances, while the plant itself maybe largely unknown. The features assumed known are the output's functional dependence on states which is essentially the output definition, and the steady-state equation relating the multiple inputs and the output of interest. Simulations have shown good disturbance rejection in fuel utilization through input shaping. This idea is abstracted to linear multi-variable systems to provide conditions when this approach is applicable. The analysis is carried out in time-domain as well as in frequency domain (through singular value analysis). The type of output variables that are amenable to transient control using this approach is derived through analysis. It is shown that the fuel utilization, although inherently nonlinear within the nonlinear dynamics of the fuel cell, has some similarities with the linear abstraction that leads to the observed transient control.

13:50-14:10 MoBT4.2

Enhancing Energy Harvesting System Using Materials with Fractional Order Stiffness, pp. 486-490

Kwuimy, Cedrick	VILLANOVA Univ. Mech Eng
Nataraj, 'Nat' C.	Villanova Univ.
Litak, Grzegorz	Department of Applied Mechanics, Lublin Univ. of Tech.

A bistable mechanical system having fractional order restoring force is considered for possible energy harvesting. The effects of the fractional order stiffness a on the crossing well dynamics (large amplitude motion) and the output electrical power are analyzed. The harvested electric power appears to be efficient for deterministic and random excitation, for small $alpha$. High level noise intensity was found to reduce the output power in the region of resonance and surprisingly increases the out up in other region of a. For larger enough amplitude of harmonic excitation this effect is realized in a stochastic resonance.

14:10-14:30 MoBT4.3

Maximum Power Point Tracking of Multi-String Photovoltaic Array Via Simultaneous Perturbation Stochastic Approximation, pp. 491-498

Xiao, Yan	The Univ. of Texas at Dallas
Li, Yaoyu	Univ. of Texas at Dallas
Seem, John E.	Johnson Controls Inc.
Rajashekara, Kaushik	Univ. of Texas at Dallas

This paper presents a Maximum Power Point Tracking (MPPT) strategy for multi-string photovoltaic (PV) systems using the Simultaneous Perturbation Stochastic Approximation (SPSA) algorithm. The multi-string PV system considered is a decentralized control configuration, controlling the voltage reference to each PV module but based on the feedback of the total power at the DC bus. This requires only one pair of voltage and current measurements. The MPPT control problem for such topology of multi-string PV systems features a high input dimension, which can dramatically slow down the searching process for the real-time optimization process involved. The SPSA algorithm is considered in this study due to its remarkable capability of fast convergence for high dimensional search problems endorsed by various applications recently. Simulation study is performed for an 8-string PV system, and experimental study is performed for a 4-string PV system. Good performances are observed for both simulation and experimental results.

14:30-14:50 MoBT4.4

System Level Dynamic Modeling Framework Being Developed at Clemson University's Wind Turbine Drivetrain Testing Facility, pp. 499-508

Schkoda, Ryan	Clemson Univ.
Bulgakov, Konstantin	Clemson Univ.
Addepalli, Kalyan Chakravarthy	Clemson Univ.
Haque, Imtiaz	Clemson Univ.

This paper describes the system level, dynamic modeling and simulation strategy being developed at the Wind Turbine Drivetrain Testing Facility (WTDTF) at Clemson University's Restoration Institute in North Charleston, SC, USA. An extensible framework that allows various workflows has been constructed and used to conduct preliminary analysis of one of the facility's test benches. The framework dictates that component and subsystem models be developed according to a list of identified needs and modeled in software best suited for the particular task. Models are then integrated according to the desired execution target. This approach allows for compartmentalized model development which is well suited for collaborative work. The framework has been applied to one of the test benches and has allowed researches to begin characterizing its behavior in the time and frequency domain.

14:50-15:10 MoBT4.5

Modeling and Respose Analysis of Piezoelectric Flag in Wind Flow, pp. 509-516

Wynn, Logan	The Univ. of Alabama
Truitt, Andrew	The Univ. of Alabama
Heim, Isaac	Univ. of Alabama
Mahmoodi, Nima	The Univ. of Alabama

Within the past decade, research in the piezoelectric energyharvesting field has grown significantly concerning material selection, device configurations, and actuation methods. Oscillating cantilevered piezoelectric energy harvesters are one of the more common designs. The flag is modeled as a cantilevered Euler-Bernoulli beam with a low modulus of elasticity, and the representative equation for this is broadly accepted. The wind pressure is modeled by a method that is apparently well accepted in the aerospace field. Among other modeling assumptions, the partial differential equation is considered separable. Once separated, the spatial equation is adjusted using an auxiliary function in order to determine the mode shapes. With the mode shapes characterized, the time function is rendered, which can yield representations for either a damped or undamped system. Individually, these time functions are combined with the adjusted spatial function using the Galerkin method. Plotted results represent the periodic, two-dimensional system response over time.

15:10-15:30 MoBT4.6

*FUZZY ADAPTIVE OUTPUT FEEDBACK CONTROL STRATEGY for STANDALONE WIND ENERGY CONVERSION SYSTEMS**

Nguyen, Hoa	Idaho State Univ.
Naidu, D. Subbaram	Idaho State Univ.

An essential control objective of wind energy conversion systems (WECSs) is to maximize the conversion of wind energy into electrical energy. This control objective is difficult to achieve using linear control techniques because the WECSs are time-varying and highly nonlinear. In this paper, we propose a nonlinear fuzzy adaptive output feedback control strategy to achieve the optimum wind power extraction of the WECSs. The control strategy is based on the input-output feedback linearization and fuzzy approximation of controller synthesized to take care of the nonlinear, time-varying plant parameter changes. Numerical simulation results verify the superiority of the proposed control strategy in comparison with the nonlinear feedback linearization strategy.

MoBT5 Tent B

System Identification and Therapeutic Control in Bio-Systems
(Invited session)

Chair: Hahn, Jin-Oh	Univ. of Maryland
Co-Chair: Fazeli, Nima	Univ. of Maryland Coll. Park
Organizer: Hahn, Jin-Oh	Univ. of Maryland
Organizer: Asada, H. Harry	Massachusetts Inst. of Tech.

13:30-13:50 MoBT5.1

Prediction of Icu In-Hospital Mortality Using Artificial Neural Networks (I), pp. 517-525

Xia, Henian	Univ. of Tennessee

Keeney, Nathan	Univ. of Tennessee
Daley, Brian	Univ. of Tennessee Medical Center
Petrie, Adam	Univ. of Tennessee
Zhao, Xiaopeng	Univ. of Tennessee

This work aims to predict in-hospital mortality in the open-source Physionet ICU database from features extracted from the time series of physiological variables using neural network models and other machine learning techniques. We developed an effective and efficient greedy algorithm for feature selection, reducing the number of potential features from 205 to a best subset of only 47. The average of five trials of 10-fold cross validation shows an accuracy of (86.23±0.14)%, a sensitivity of (50.29±0.22)%, a specificity of (92.01±0.21)%, a positive prediction value of (50.29±0.50)%, a negative prediction value of (92.01±0.00)%, and a Lemeshow score of 119.55±9.87. By calibrating the predicted mortality probability using an optimization approach, we can improve the Lemeshow score to 27.51±4.38. The developed model has the potential for application in ICU machines to improve the quality of care and to evaluate the effect of treatment or drugs.

13:50-14:10 MoBT5.2

Integrated Mechanistic-Empirical Modeling of Cellular Response Based on Intracellular Signaling Dynamics (I), pp. 526-530

Mayalu, Michaelle	Massachusetts Inst. of Tech.
Asada, H. Harry	Massachusetts Inst. of Tech.

A hybrid modeling framework integrating a highly specific mechanistic model with highly abstract empirical model is presented. With the growing interest in the scientific and medical community for identification of therapeutic targets in treatment of disease, it is necessary to develop predictive models that can describe cellular behavior in response to environmental cues. Intracellular signaling pathways form complex networks that regulate cellular response in both health and disease. Mechanistic (or white-box) models of biochemical networks are often unable to explain comprehensive cellular response due to lack of knowledge and/or intractable complexity (especially in events distal from the cell membrane). Empirical (or black-box) models may provide a less than accurate representation of cellular response due to data deficiency and/or loss of mechanistic detail. In the proposed framework, we use a mechanistic model to capture early signaling events and apply the resulting generated internal signals (along with external inputs) to a downstream empirical sub-model. The key construct in the approach is the treatment of a cell's biochemical network as an encoder that creates a functional internal representation of external environmental cues. The signals derived from this representation are then used to inform downstream behaviors. Using this idea, we are able to create a comprehensive framework that describes important mechanisms with sufficient detail, while representing complex or unknown mechanisms in a more abstract form. The model is verified using published biological data describing T-Cells in immune response.

14:10-14:30 MoBT5.3

Modeling and System Identification of Arterial Hemodynamics in Humans (I), pp. 531-538

Rashedi, Mohammad	Univ. of Alberta
Fazeli, Nima	Univ. of Maryland Coll. Park
Alyssa, Chappell	Univ. of Alberta
Wang, Shaohua	Univ. of Alberta
MacArthur, Roderick	Univ. of Alberta
McMurtry, M. Sean	Univ. of Alberta
Finegan, Barry	Univ. of Alberta
Hahn, Jin-Oh	Univ. of Maryland

This paper seeks to determine the validity of two distinct tube-load models relating central aortic blood pressure to peripheral blood pressure in humans. Specifically a single-tube model (1-TL) and a serially connected two-tube (2-TL) model, both terminating in a Windkessel load, are considered as representations of the central aortic-peripheral arterial path. The validity and fidelity of the two models was assessed and compared quantitatively by fitting central aortic, radial and femoral blood pressures collected from 8 patients. Both models fitted the BP waveform pairs effectively, and were capable of estimating pulse travel time (PTT) accurately; also the model derived frequency responses were close to the empiric transfer function estimates derived from central and peripheral BP measurements. The 2-TL model was consistently better than 1-TL with statistical significance in terms of accuracy of the central aortic BP waveform, the average waveform RMSE were 2.52 mmHg versus 3.24 mmHg respectively ($p<0.05$).

14:30-14:50 MoBT5.4

Active Non-Intrusive System Identification for Cardiovascular Monitoring Part Ii: Development of System Identifiction Algorithm (I), pp. 539-548

Fazeli, Nima	Univ. of Maryland Coll. Park
Hahn, Jin-Oh	Univ. of Maryland

In this paper, we present an innovative active non-intrusive system identification approach to cardiovascular monitoring. The proposed approach is based on a dual collocated actuator-sensor system for cardiovascular system identification, in which the actuators actively excite the arterial tree to create rich and informative trans-mural pressure waves traveling in the arterial tree, which are then non-intrusively measured by the collocated sensors. In our previous work, we developed a mathematical model to reproduce the propagation of intra-vascular (arterial) and extra-vascular (artificial) pressure waves along the arterial tree. Then, we used a dual (radial-femoral) blood pressure cuff system as a prototype dual collocated actuator-sensor system to demonstrate the proposed methodological framework to create rich trans-mural pressure waves as well as to non-intrusively reconstruct them from sensor measurements. In this follow-up work, we propose a novel system identification algorithm to derive cardiovascular system dynamics and reconstruct central aortic blood pressure waveform from the trans-mural pressure waves observed at the peripheral locations. It was successfully demonstrated that the system identification algorithm was able to reconstruct the central aortic blood pressure accurately, and that its performance was superior to the passive non-intrusive approach.

14:50-15:10 MoBT5.5

Improving Cardiopulmonary Resuscitation (CPR) by Dynamic Variation of CPR Parameters (I), pp. 549-554

Jalali, Ali	Villanova Univ.
Berg, Robert A.	Children's Hospital of Philadelphia
Nadkarni, Vinay M.	Children's Hospital of Philadelphia
Nataraj, 'Nat' C.	Villanova Univ.

Cardiopulmonary resuscitation (CPR) is a commonly used procedure and plays a critical role in saving the lives of patients suffering from cardiac arrest. This paper is concerned with the design of a dynamic technique to optimize the performance of CPR and to consequently improve its outcome, the survival rate. Current American Heart Association (AHA) guidelines treat CPR as a static procedure with fixed parameters. These guidelines set fixed values for CPR parameters such as compression to ventilation ratio, chest compression depth, etc., with an implicit assumption that they are somehow "optimal," which has not been really substantiated. In this study, in a quest to improve this oft-used procedure, an interactive technique has been developed for dynamically changing the CPR parameters. Total blood gas delivery which is combination of systemic oxygen delivery and carbon dioxide delivery to the lungs has been defined as the objective function, and a sequential optimization procedure has been explored to optimize the objective function by dynamically adjusting the CPR parameters. The results of comparison between the sequential optimization procedure and the global optimization procedure show that the sequential optimization procedure could significantly enhance the effectiveness of CPR.

15:10-15:30	MoBT5.6

Ankle Mechanical Impedance under Muscle Fatigue (I), pp. 555-559

Wang, Shuo — Massachusetts Inst. of Tech.
Lee, Hyunglae — Mass. Inst. of Tech.
Hogan, Neville — Massachusetts Inst. of Tech.

This paper reports preliminary results on the effects of ankle muscle fatigue on ankle mechanical impedance. The experiment was designed to induce fatigue in the Tibialis Anterior and Triceps Surae muscle group by asking subjects to perform isometric contractions against a constant ankle torque generated by the Anklebot, a backdriveable robot that interacts with the ankle in two degrees of freedom. Median frequencies of surface electromyographic signals collected from Tibialis Anterior and Triceps Surae muscle group were evaluated to assess muscle fatigue. Using a standard multi-input and multi-output stochastic impedance identification method, multivariable ankle mechanical impedance was measured in two degrees of freedom under muscle fatigue. Preliminary results indicate that, for both Tibialis Anterior and Triceps Surae muscle group, ankle mechanical impedance decreases in both the dorsi-plantarflexion and inversion-eversion directions under muscle fatigue. This finding suggests that decreasing ankle impedance with muscle fatigue may help to develop joint support systems to prevent ankle injuries caused by muscle fatigue.

MoBT6	Room 134

Control, Monitoring, and Energy Harvesting of Vibratory Systems: Active Vibration Control-2 (Invited session)

Chair: Sipahi, Rifat	Northeastern Univ.
Co-Chair: Caruntu, Dumitru	Univ. of Texas Pan American
Organizer: Zuo, Lei	Stony Brook Univ. - SUNY
Organizer: Tang, Jiong	Univ. of Connecticut
Organizer: Sipahi, Rifat	Northeastern Univ.
Organizer: Caruntu, Dumitru	Univ. of Texas Pan American
Organizer: Nishimura, Hidekazu	Keio Univ.
Organizer: Kajiwara, Itsuro	Hokkaido Univ.

13:30-13:50	MoBT6.1

Acceleration Control of Powered Wheelchairs with Nil-Mode-Exciting Profiler Considering Vibration Characteristic of Human Body (I), pp. 560-567

Takahashi, Masaki — Keio Univ.
Okugawa, Kyohei — Keio Univ.

Recently, the number of people who need powered wheelchairs has been increasing due to aging society. Riding comfort is very important for people who use powered wheelchairs. In addition, wheelchairs must respond well to a reference velocity input with a joystick controller because collision must be avoided. The relation between ride comfort and fast response is a trade-off one. To solve these problems, a suitable reference torque signal should be designed. Thus, we propose a control system for powered wheelchairs that can reduce the vibration caused to the human head and upper body and achieve a fast response. Moreover, to guarantee robustness against parameter variations such as human weight and the friction of joints, a two-degrees-of-freedom control system that consists of feed-forward and feedback controllers was designed. We designed a feed-forward control input that uses the nil-mode-exciting (NME) profiler, which is called a “preshaping profiler”. This preshaping profiler has a low-pass-shaped frequency characteristic. Therefore, no residual vibrations are caused at a frequency higher than a certain frequency (the sampling function frequency). In this study, the sampling function frequency was designed in consideration of both vibration and response. To improve robustness against the variation of model parameters such as weight and friction, we designed a wheel velocity feedback control added to the feed-forward control. To verify the effectiveness of the proposed method, several numerical simulations were carried out.

13:50-14:10	MoBT6.2

A Trajectory Shaping Approach for Suppressing the Fundamental Vibratory Mode in Strain Wave Gearing Mechanisms (I), pp. 568-576

Chan, Michael — Univ. of California, Berkeley
Tomizuka, Masayoshi — Univ. of California, Berkeley

While strain wave gearing mechanisms, such as harmonic drives, have many practical benefits when properly utilized, they also create challenging problems for control engineers. Namely, these flexible gear reduction mechanisms can create output vibrations which cannot be directly measured or controlled by the actuator. In this paper, an input shaping approach will be proposed to pre-compensate the desired output trajectory to account for the transmission dynamics such that the system's actual output will follow the original desired trajectory. Several system parameters need to be empirically identified prior to using the proposed procedure. This identification process will also be outlined. Both simulation and experimental results on a 6 degree of freedom industrial robot will be provided to demonstrate the effectiveness of the proposed approach.

14:10-14:30	MoBT6.3

Semi-Active Control Methodology for Control of Air Spring-Valve-Accumulator System (I), pp. 577-586

Robinson, William Daniel — John Deere
Kelkar, Atul — Iowa State Univ.
Vogel, Jerald — IVS, Inc

This paper presents a semi-active control methodology for controlling the vibration of a pneumatic air spring-valve-accumulator system. Three controllers are presented and compared, along with experimental results. Due to the semi-active nature of this system, each controller uses a skyhook switching algorithm, along with a set-point plus PI tracking algorithm to track a desired reference signal. Some combination of pressure and displacement (or relative displacement) sensor feedback is used in each case. The desired reference control signal is generated by three different methods. The first method uses an optimal LQI (Linear Quadratic Impulse) controller generated from Covariance Control Theory. The second method uses a modified skyhook algorithm, and the third method uses a command directly proportional to the relative displacement. The second two methods use the first method (LQI) to tune the required controller gains off-line.

14:30-14:50	MoBT6.4

Control of a Nonlinear Pressure-Regulating Engine Bleed Valve in Aircraft Air Management Systems (I), pp. 587-592

Cooper, John — Univ. of Connecticut
Cao, Chengyu — Univ. of Connecticut
Tang, Jiong — Univ. of Connecticut

This paper presents an adaptive control algorithm, based on the L1 adaptive control method, for controlling the pressure of engine bleed air in a commercial aircraft. The pressure is affected by a control valve that is part of a larger air management system which includes control valves for temperature and flow rate as well as a heat exchanger or precooler. A system model is presented including valve hysteresis due to backlash and dry friction. Simulations are conducted for a control valve subject to unmeasured disturbance, and the adaptive control results are compared to those of a traditional proportional-integral controller.

14:50-15:10	MoBT6.5

Modal Analysis of a Motorcycle Motion During Braking for Its Stabilization Control System Design (I), pp. 593-600

Murakami, Shintaroh — Keio Univ.
Nishimura, Hidekazu — Keio Univ.

In this paper, modal motion of a motorcycle during braking is

analyzed to clarify influence of a stabilization control system designed to the modes. A thirteen degree-of-freedom nonlinear state-space model including rider's motion is linearized around an equilibrium point of quasi-steady state straight running with constant deceleration, and the modal analysis is carried out using the linearized state-space models. Conducting mode separation and performing simulations utilizing the linearized state-space models, the behavior of the modes including capsize, weave, and wobble modes are analyzed. The characteristic of each mode is clarified from relationships among the impulsive responses of simulations and the eigenvectors obtained from eigenanalysis. Furthermore, the influence of a motorcycle stabilization control system to each mode is analyzed from simulation results.

15:10-15:30 MoBT6.6

Vehicle Stability Control in Anti-Lock Braking System on Split-U Road Surface Considering Driver in the Loop (I), pp. 601-608

Yu, Liangyao	Tsinghua Univ.
You, Changxi	Tsinghua Univ.
Song, Jian	Tsinghua Univ.

With the introduction and development of Anti-lock Braking System in modern vehicles, remarkable progress in brake efficiency and brake stability has been achieved. However, it is a significant challenge to deal with the control law in certain critical situations, especially on split-μ road surface. In low vehicle velocity, as some standards and regulations specified, the stability in such situation is comparably easy to be achieved. But with the vehicle velocity increasing, the driver behavior contributes a large impact on the trajectory maintenance and easily causes sympathetic vibration of the vehicle because of the unexpected synchronization between the driver input and control law output, which could be very dangerous. This paper presents the research work in vehicle stability control when Anti-lock Braking System is activated at split-μ road surface. The principal contribution of this work is that the driver behavior is taken into account and the control law is tuned to adapt to this situation, which effectively maintains the stability of the vehicle without compromising the brake efficiency.

MoBT7 Room 138

Nonlinear Control (Contributed session)

Chair: Messner, William	Tufts Univ.
Co-Chair: Ren, Beibei	Texas Tech. Univ.

13:30-13:50 MoBT7.1

UDE-Based Robust Control for a Class of Non-Affine Nonlinear Systems, pp. 609-614

Ren, Beibei	Texas Tech. Univ.
Zhong, Qing-Chang	The Univ. of Sheffield

In this paper, the UDE (uncertainty and disturbance estimator) based robust control is investigated for a class of non-affine nonlinear systems in a normal form. Control system design for non-affine nonlinear systems is one of the most difficult problems due to the lack of mathematical tools. This is also true even for the exact known non-affine systems because of the difficulty in explicitly constructing the control law. It is shown that the proposed UDE-based robust control strategy leads to a stable system. The most important features of the approach are that (i) by adding and subtracting the control term u, the original non-affine form is transformed into a semi-affine form, which not only simplifies the control design procedure, but also avoids the singularity problem of the controller; (ii)the employment of UDE makes the estimation of the lumped uncertain term which is a function of control input, states and disturbances possible, rather than states alone; and (iii) it does not require any knowledge (e.g., bounds) about the uncertainties and disturbances, except the information about the bandwidth, during the design process. The stability of the closed-loop system is established. Effectiveness of the proposed approach is demonstrated through application to the hard disk driver control problem.

13:50-14:10 MoBT7.2

Invariance Control of a Class of Cascade Nonlinear Systems with Input Unmodeled Dynamics, pp. 615-622

Wu, Caiyun	State Key Lab. of Synthetical Automation for Process Indus
Dimirovski, Georgi Marko	Dogus Univ. of Istanbul
Zhao, Jun	Northeastern Univ.
Ma, Ruicheng	Liaoning Univ.

The paper addresses the invariance control for a class of cascade nonlinear systems with unmodeled dynamics appearing at the input. A sufficient condition for the robust invariance control of the system under consideration is derived. Based on the methods of passivity and switching control of states of the linear subsystem, both the stabilization of the linear subsystem and the positive invariance of the prespecified region in state space can be ensured. Under some additional assumptions, the whole system is semi-global asymptotically stable. A simulation example is given to demonstrate the effectiveness of the proposed design procedure.

14:10-14:30 MoBT7.3

Nonlinear Compensation for High Performance Feedback Systems with Actuator Imperfections, pp. 623-631

Mock, Cameron	Univ. of Wyoming
Hamilton, Zachary	Univ. of Wyoming
Carruthers, Dustin	Left Hand Design Corp.
OBrien, John F.	Univ. of Wyoming

Measures to reduce control performance for greater robustness (e.g. reduced bandwidth, shallow loop roll-off) must be enhanced if the plant or actuators are known to have nonlinear characteristics that cause variations in loop transmission. Common causes of these nonlinear behaviors are actuator saturation and friction/stiction in the moving parts of mechanical systems. Systems with these characteristics that also have stringent closed loop performance requirements present the control designer with an extremely challenging problem. A design method for these systems is presented that combines very aggressive Nyquist-stable linear control to provide large negative feedback with nonlinear feedback to compensate for the effects of multiple nonlinearities in the loop that threaten stability and performance. The efficacy of this approach is experimentally verified on a parallel kinematic mechanism with multiple uncertain nonlinearities used for vibration suppression.

14:30-14:50 MoBT7.4

Proportional Nonlinear Systems: A Liable Class for Global Exponential State-Feedback Stabilization, pp. 632-639

Carravetta, Francesco	IASI-CNR

We introduce, through an analysis overall restricted, for the sake of simplicity, in two-dimensions, the class of proportional systems, a nice subclass of the Sigma/Pi-algebraic nonlinear systems that we formerly introduced in another paper as a sort of 'nonlinear paradigm' linking nonlinear to bilinear systems. Also we define a decomposition, which every Sigma/Pi-algebraic system undergoes, into the cascade of a driver, medial and final bilinear sub-system, having the same input-output behavior as the original. We show that a systematic way for global feedback stabilization can be developed for the class of proportional systems, leading to the global feedback exponential stabilization of the medial part under some 'natural' condition of non singularity. We show in an example the capability of the proposed method to achieving global feedback stabilization for the original system as well.

14:50-15:10 MoBT7.5

Nonlinear Control of an Unmanned Amphibious Vehicle, pp. 640-644

Alvarez, Jose	Florida Atlantic Univ.
Bertaska, Ivan Rodrigues	Florida Atlantic Univ.
von Ellenrieder, Karl	Florida Atlantic Univ.

The development and implementation of an experimental sliding mode control law for a 2.5 meter long unmanned amphibious vehicle (the DUKW-Ling) when waterborne is presented. A first-order sliding control surface is used for surge tracking error when a P controller is used to minimize the heading error in the system. The state of the vehicle is measured using onboard sensors with the ability to record surge, sway, yaw and position of the vehicle in real-time. Experimental data collected show the ability of the vessel to maintain a desired heading and speed. This article emphasizes the ability of sliding-mode controller to respond to the unpredictable and random water and wind currents acting on the vehicle.

15:10-15:30	MoBT7.6

Controller Design for Nonlinear Multi-Input/Multi-Output Systems Using the Contoured Robust Controller Bode Plot, pp. 645-653

Taylor, Jd	Carnegie Mellon Univ.
Messner, William	Tufts Univ.

In this paper, a novel approach to controller design for nonlinear multi-input/multi-output (MIMO) systems is presented based on the Contoured Robust Controller Bode (CRCBode) plot. CRCBode plots show level-sets of a robust metric and identify certain ``forbidden regions'' on the controller Bode magnitude and phase plots such that intersections of the controller frequency response with these forbidden regions indicate that a robust stability and performance criterion is violated. Nonlinear system dynamics are included as a structured uncertainty set consisting of linearizations about several operating points. To demonstrate this approach, we design a controller for a MIMO high-speed, low-tension magnetic tape drive memory system. A preliminary approximate inverse step is described, followed by several loop-shaping design iterations to eliminate all intersections with the forbidden regions on the CRCBode diagrams. Finally, the CRCBode compensator is compared to one generated using an automated H-infinity synthesis algorithm.

MoCT1	Paul Brest East

System Identification and Estimation for Automotive Applications (Invited session)

Chair: Canova, Marcello	The Ohio State Univ.
Co-Chair: Hall, Carrie	Purdue Univ.
Organizer: Yan, Fengjun	McMaster Univ.
Organizer: Shahbakhti, Mahdi	Michigan Tech. Univ.
Organizer: Canova, Marcello	The Ohio State Univ.
Organizer: Hall, Carrie	Purdue Univ.
Organizer: Kolodziej, Jason	Rochester Inst. of Tech.
Organizer: Scacchioli, Annalisa	New York Univ.

16:00-16:20	MoCT1.1

Robust Sideslip Angle Estimation for Lightweight Vehicles Using Smooth Variable Structure Filter (I), pp. 654-661

Huang, Xiaoyu	The Ohio State Univ.
Wang, Junmin	The Ohio State Univ.

In the design of vehicle stability control (VSC) systems for ground vehicles, sideslip angle plays a vital role and its estimation has long been an active research topic. Accurate estimation of sideslip angle is more difficult for lightweight vehicles (LWVs) because their parameters are prone to significant changes with loading conditions—the amount and position of the payload. In this paper, a robust sideslip angle estimator based on a recently emerging smooth variable structure filter (SVSF) is presented. This sideslip angle estimator is suitable for LWVs because it is almost non-sensitive to the changes of the system parameters. A four-state vehicle lateral dynamic model including a pseudo-Burckhardt tire model is employed in the filter design. Compared with the widely utilized extended Kalman filter (EKF), the SVSF shows much better robustness against modeling errors. It is also more favorable in terms of tuning effort and computational speed. Simulation studies were conducted based on a high-fidelity vehicle model in CarSim®, where the vehicle took the form of a lightweight electric ground vehicle with independent in-wheel motors. The performance of the SVSF was shown by comparisons against the EKF under different settings for model parameters.

16:20-16:40	MoCT1.2

Real-Time Battery Model Identification Using a Two Time-Scaled Approach (I), pp. 662-668

Hu, Yiran	General Motors R/D
Wang, Yue-Yun	General Motors Company

Battery state estimation (BSE) is one of the most important design aspects of an electrified propulsion system. It includes important functions such as state-of-charge estimation which is essentially for the energy management system. A successful and practical approach to battery state estimation is via real time battery model parameter identification. In this approach, a loworder control-oriented model is used to approximate the battery dynamics. Then a recursive least squares is used to identify the model parameters in real time. Despite its good properties, this approach can fail to identify the optimal model parameters if the underlying system contains time constants that are very far apart in terms of time-scale. Unfortunately this is the case for typical lithium-ion batteries especially at lower temperatures. In this paper, a modified battery model parameter identification method is proposed where the slower and faster battery dynamics are identified separately. The battery impedance information is used to guide how to separate the slower and faster dynamics, though not used specifically in the identification algorithm. This modified algorithm is still based on least squares and can be implemented in real time using recursive least squares. Laboratory data is used to demonstrate the validity of this method.

16:40-17:00	MoCT1.3

Robust Sideslip Angle Estimation for Over-Actuated Electric Vehicles: A Linear Parameter Varying System Approach (I), pp. 669-677

Chen, Yan	Ohio State Univ.
Wang, Junmin	The Ohio State Univ.

A new estimation method for estimating the vehicle sideslip angle, mainly based on a linear parameter varying (LPV) model with independently estimated tire friction forces, is proposed for electric ground vehicles (EGVs) with four independent in-wheel motors. By utilizing the individual wheel dynamics, the longitudinal ground friction force is estimated from a PID observer based on a descriptor linear system approach. Moreover, the lateral ground friction force for each wheel is estimated through the friction ellipse relationship given the estimated longitudinal friction force, without relying on explicit tire models. Since the estimation errors of friction forces may bring parameter uncertainty for the LPV system, robust analysis with desired H-infinity performance is given for the observer design of the LPV modeling. This method is specially proposed for large tire slip angles and lateral friction forces. Simulation results for different maneuvers validate this novel sideslip angle estimation method.

17:00-17:20	MoCT1.4

Vehicle Health Inferencing Using Feature-Based Neural-Symbolic Networks (I), pp. 678-682

Aasted, Christopher	Harvard Medical School / Boston Children's Hospital
Lim, Sun-Wook	New York Inst. of Tech.
Shoureshi, Rahmat	New York Inst. of Tech.

In order to optimize the use of fault tolerant controllers for unmanned or autonomous aerial vehicles, a health diagnostics system is being developed. To autonomously determine the effect of damage on global vehicle health, a feature-based neural-symbolic network is utilized to infer vehicle health using historical data. Our current system is able to accurately characterize the extent of vehicle damage with 99.2% accuracy when tested on prior incident data. Based on the results of this work, neural-symbolic networks appear to be a useful tool for diagnosis of global vehicle health based on features of subsystem diagnostic information.

17:20-17:40	MoCT1.5

Online Adaptive Residual Mass Estimation in a Multicylinder Recompression HCCI Engine (I), pp. 683-691

Larimore, Jacob	Univ. of Michigan
Jade, Shyam	Univ. of Michigan
Hellström, Erik	Univ. of Michigan
Vanier, Julien	Robert Bosch LLC.
Jiang, Li	Robert Bosch LLC
Stefanopoulou, Anna G.	Univ. of Michigan

This work presents two advances to the estimation of homogeneous charge compression ignition (HCCI) dynamics. Combustion phasing prediction in control-oriented models has been achieved by modeling the in-cylinder temperature and composition dynamics, which are dictated by the large mass of residuals trapped between cycles. As such, an accurate prediction of the residual gas fraction as a function of the variable valve timing is desired. Energy and mass conservation laws applied during the exhaust valve opening period are complemented with online in-cylinder pressure measurements to predict the trapped residual mass in real time. In addition, an adaptive parameter estimation scheme uses measured combustion phasing to adjust the residual mass prediction. Experimental results on a multicylinder gasoline HCCI engine demonstrate the closed loop residual estimation's ability to compensate for modeling errors, cylinder to cylinder variations, and engine wear. Additionally it is shown that using the adaptive parameter estimation reduces the model parameterization effort for a multicylinder engine.

17:40-18:00	MoCT1.6

Cycle-By-Cycle Based In-Cylinder Temperature Estimation for Diesel Engines (I), pp. 692-699

Chen, Song	McMaster Univ.
Yan, Fengjun	McMaster Univ.

The in-cylinder temperature information is critical in the field of auto-ignition control in advanced combustion modes. However, the in-cylinder temperature is hard to be directly measured at low cost in production engines. In this paper, a cycle-by-cycle estimation method is proposed for the in-cylinder temperature at the crank angle of intake valve closing (IVC). Through investigating the thermodynamics of the in-cylinder temperture, an Extended Kalman Filter (EKF) based method was devised by utilizing the measurable temperature information from the intake and exhaust manifolds. The proposed method was validated through high-fidelity GT-Power engine model simulation.

MoCT2	Room 123

Human Assistive Systems and Wearable Robots: Design and Control (Invited session)

Chair: Ueda, Jun	Georgia Inst. of Tech.
Co-Chair: Deshpande, Ashish	Univ. of Texas
Organizer: Ueda, Jun	Georgia Inst. of Tech.
Organizer: Deshpande, Ashish	Univ. of Texas

16:00-16:20	MoCT2.1

Kinematics and Dynamics of a Biologically Inspired Index Finger Exoskeleton (I), pp. 700-709

Agarwal, Priyanshu	The Univ. of Texas at Austin
Hechanova, Arnold	The Univ. of Texas at Austin
Deshpande, Ashish	Univ. of Texas

Rehabilitation of upper extremity, especially hands, is critical for the restoration of independence in activities of daily living for individuals suffering from hand disabilities. In this work, we propose a biologically-inspired design of an index finger exoskeleton. The design has passive stiffness at each joint with antagonistic tendon driven actuation allowing for (1) improved kinematic and dynamic compatibility for effective therapy; and (2) conformation of exoskeleton and finger joints axes of rotation. We present a kinematics and dynamics model of the coupled index finger-exoskeleton system that incorporates human-like passive torques at the metacarpophalangeal (MCP), proximal interphalangeal (PIP) and distal interphalangeal (DIP) joints. We carry out simulations using this coupled system model to study the role of passive stiffness on workspace and tendon forces, actuator force and displacement requirements, and reaction forces and moments acting at the finger joints for an index finger flexion-extension task. Results show that accurately modeling the coupled system can help in optimizing the design and control of the device, thus, exploiting its passive dynamics for effective functioning.

16:20-16:40	MoCT2.2

Nonlinear Passive Elements Using Cam-Based Springs for Powered Robotic Ankles (I), pp. 710-718

Realmuto, Jonathan	U. of Washington
Klute, Glenn	VA Puget Sound Health Care System
Devasia, Santosh	Univ. of Washington

There is increasing interest in powered prosthesis. To reduce energy and power requirements on the active system, current systems, such as powered ankle prosthetics, utilize a combination of passive and active components. By storing and releasing energy during gait, the passive component reduces the energy/power requirements of the active component. Therefore, it is advantageous to maximize the use of the passive component for achieving the desired motion. Typically, the passive component utilizes elastic elements such as springs, which cannot be easily adjusted to achieve a desired optimal nonlinear response. In this work, we report the use of a cam profile to achieve a general desired nonlinear response. The results show that the added design flexibility (to achieve nonlinear response of the passive element) can substantially reduce the energy/power requirement of the active component.

16:40-17:00	MoCT2.3

Novel Design of a Passive Variable Stiffness Joint Mechanism: Inspiration from Biomechanics of Hand Joints (I), pp. 719-726

Kuo, Pei-Hsin	Univ. of Texas
Deshpande, Ashish	Univ. of Texas

Passive variable stiffness at the human hand joints is shown to be critical for achieving stable and dexterous grasping and manipulation. Our long-term goal is to implement it in robotic hand joints. We introduce a novel design, using linear springs and non-circular cam, for a variable stiffness joint mechanism that mimics the passive stiffness characteristics of human hand joints. We present a methodology based on the principle of virtual work for synthesizing the cam shape in the joint. Key innovations of our design are a) human-like joint stiffness profile, b) large joint range of motion, and c) modular arrangement for varying torque range. We have built a prototype for validating our approach and the experimental results demonstrate that the proposed joint mechanism fulfills the design goals of our study.

17:00-17:20	MoCT2.4

Design of a Minimally Actuated Medical Exoskeleton with Mechanical Swing-Phase Gait Generation and Sit-Stand Assistance (I), pp. 727-735

Tung, Wayne Yi-Wei	Univ. of California, Berkeley
McKinley, Michael G.	Univ. of California
Kazerooni, Homayoon	Univ. of California at Berkeley
Pillai, Minerva Vasudevan	Univ. of California, Berkeley
Reid, Jason I.	Univ. of California, Berkeley

Lower-extremity powered exoskeletons have traditionally used four to ten powered degrees of freedom to provide gait assistance for individuals with spinal cord injury (SCI). Systems with numerous high-impedance powered degrees of freedom commonly suffer from cumbersome walking dynamics and decreased utility due to added weight and increased control complexity. We propose a new approach to powered exoskeleton design that minimizes actuation and control complexity by embedding intelligence into the hardware. This paper describes a minimalistic system that uses a single motor for each exoskeleton leg in conjunction with a bio-inspired hip-knee coupling mechanism to enable users to walk, sit, and stand. Operating in concert with a custom orthotic knee joint, the exoskeleton hip joint has been designed to mimic the biarticular coupling of human leg muscles thus allowing a single actuator to power both hip and knee motions simultaneously. The implementation of this design resulted in a system that provides comparable performance to existing exoskeletons. This system has been tested on paraplegic subjects and has successfully enabled patients to stand up, sit down, and ambulate in numerous real world situations.

17:20-17:40 MoCT2.5

Comparison of Ultrasound Muscle Stiffness Measurement and Electromyography towards Validation of an Algorithm for Individual Muscle Control (I), pp. 736-745

Brown, Ellenor	Georgia Inst. of Tech.
Aomoto, Kazuya	Nara Inst. of Science and Tech.
Ikeda, Atsutoshi	Nara Inst. of Science and Tech.
Ogasawara, Tsukasa	Nara Inst. of science and Tech.
Yoshitake, Yasuhide	National Inst. of Fitness and Sports
Shinohara, Minoru	Georgia Inst. of Tech.
Ueda, Jun	Georgia Inst. of Tech.

The ability to control individual muscle activity is widely applicable in clinical diagnostics, training, and rehabilitation. Inducing muscle patterns that amplify abnormal muscle coordination can assist with early diagnosis of neuromuscular disorders. Individual muscle control also allows for targeted exercise of muscles weakened by disease, injury, or disuse. The goals of this research are to test a system for individual muscle control and introduce the use of muscle ultrasound as an alternative to electromyography (EMG). The system integrates a computational model of the right upper extremity with a robotic manipulator to predict and control muscle activity. To test the system, subjects gripped the manipulator and isometrically resisted loads applied to the hand. Muscle activity was measured via EMG and ultrasound. The system was able to induce the desired direction of muscle activity change but with limited precision. EMG measurement appeared susceptible to error due to crosstalk in the forearm.

17:40-18:00 MoCT2.6

Control of Autonomous Robots Using the Principles of Neuromodulation (I), pp. 746-753

Samanta, Biswanath	Georgia Southern Univ.
Prince, Islam	Georgia Southern Univ.

The paper presents a control approach based on vertebrate neuromodulation and its implementation on an autonomous robot platform. A simple neural network is used to model the neuromodulatory function for generating context based behavioral responses to sensory signals. The neural network incorporates three types of neurons- cholinergic and noradrenergic (ACh/NE) neurons for attention focusing and action selection, dopaminergic (DA) neurons for curiosity-seeking, and serotonergic (5-HT) neurons for risk aversion behavior. The implementation of the neuronal model on a relatively simple autonomous robot illustrates its interesting behavior adapting to changes in the environment. The integration of neuromodulation based robots in the study of human-robot interaction would be worth considering in future.

MoCT3 Tent A

Marine Vehicles (Contributed session)

Chair: Kiriakidis, Kiriakos	U.S. Naval Acad.
Co-Chair: Zhang, Feitian	Michigan State Univ.

16:00-16:20 MoCT3.1

Backstepping-Based Hybrid Target Tracking Control for a Carangiform Robotic Fish, pp. 754-762

Chen, Songlin	Harbin Inst. of Tech.
Wang, Jianxun	Michigan State Univ.
Tan, Xiaobo	Michigan State Univ.

In this paper we apply backstepping technique to develop a novel hybrid target-tracking control scheme for a arangiform robotic fish, based on a dynamic model that combines rigid-body dynamics with Lighthill's large-amplitude elongated-body theory. This hybrid controller consists of an open-loop turning controller and a closed-loop approaching controller. A hysteretic switching strategy based on the orientation error is designed. Using Lyapunov analysis, we show that the trajectory of the robotic fish will converge to the target point. The ffectiveness of the proposed control strategy is demonstrated through both simulations and experiments.

16:20-16:40 MoCT3.2

Gliding Robotic Fish and Its Tail-Enabled Yaw Motion Stabilization Using Sliding Mode Control, pp. 763-772

Zhang, Feitian	Michigan State Univ.
Tan, Xiaobo	Michigan State Univ.

Gliding robotic fish is a new type of underwater robots that combines the energy-efficiency of underwater gliders and the high maneuverability of robotic fish. The tail fin of a gliding robotic fish provides the robot more control authority, especially for the lateral motion, compared with traditional underwater gliders. In this paper, the design and development of a gliding robotic fish prototype is first presented, followed by its dynamic model. We then focus on the problem of tail-enabled yaw stabilization during gliding, where a sliding mode controller is proposed. Both simulation and experimental results are demonstrated to validate the effectiveness of the proposed controller.

16:40-17:00 MoCT3.3

Adaptive Optimal Power Trade-Off in Underwater Sensor Networks, pp. 773-782

Jha, Devesh	Pennsylvania State Univ. Univ. Park, PA
Wettergren, Thomas A.	Naval Undersea Warfare Center
Ray, Asok	Pennsylvania State Univ.

In general, sensor networks have two competing objectives: (i) maximization of network performance with respect to the probability of successful search with a specified false alarm rate for a given coverage area, and (ii) maximization of the network's operational life. In this context, battery-powered sensing systems are operable as long as they can communicate sensed data to the processing nodes. Since both operations of sensing and communication consume energy, judicious use of these operations could effectively improve the sensor network's lifetime. From these perspectives, the paper presents an adaptive energy management policy that will optimally allocate the available energy between sensing and communication operations at each node to maximize the network performance under specified constraints. With the assumption of fixed total energy for a sensor network operating over a time period, the problem is reduced to identification of a network topology that maximizes the probability of successful detection of targets over a surveillance region. In a two-stage optimization, a genetic algorithm-based meta-heuristic search is first used to efficiently explore the global design space, and then a local pattern search algorithm is used for convergence to an optimal solution. The results of performance evaluation are presented to validate the proposed concept.

17:00-17:20 MoCT3.4

Planning the Minimum Time Course for Autonomous Underwater Vehicle in Uncertain Current, pp. 783-786

Hurni, Michael — US Naval Acad.
Kiriakidis, Kiriakos — U.S. Naval Acad.
Nicholson, John — US Naval Acad.

The authors developed an approach to a ``best'' time path for Autonomous Underwater Vehicles sailing uncertain currents. The numerical optimization tool DIDO is used to compute minimum time paths for a sample of currents between ebb and flow. A simulated meta-experiment is performed where the vehicle traverses the resulting paths under different current strengths per run. The fastest elapsed time emerges from a payoff table.

17:20-17:40 MoCT3.5

An Experimental Testbed for Multi-Robot Tracking of Manifolds and Coherent Structures in Flows, pp. 787-796

Michini, Matthew — Drexel Univ.
Mallory, Kenneth — Drexel Univ.
Larkin, Dennis — Drexel Univ.
Hsieh, M. Ani — Drexel Univ.
Forgoston, Eric — Montclair State Univ.
Yecko, Philip A. — Montclair State Univ.

In this paper, we describe the development of an experimental testbed capable of producing controllable ocean-like flows in a laboratory setting. The objective is to develop a testbed to evaluate multi-robot strategies for tracking manifolds and Lagrangian coherent structures (LCS) in the ocean. Recent theoretical results have shown that LCS coincide with minimum energy and minimum time optimal paths for autonomous vehicles in the ocean. Furthermore, knowledge of these structures enables the prediction and estimation of the underlying fluid dynamics. The testbed is a scaled flow tank capable of generating complex and controlled quasi-2D flow fields that exhibit wind-driven double-gyre flows. Particle image velocimetry (PIV) is used to extract the 2D surface velocities and the data is then processed to verify the existence of manifolds and Lagrangian coherent structures in the flow. The velocity data is then used to evaluate our previously proposed multi-robot LCS tracking strategy in simulation.

17:40-18:00 MoCT3.6

Experimental Evaluation of Approach Behavior for Autonomous Surface Vehicles, pp. 797-805

Bertaska, Ivan Rodrigues — Florida Atlantic Univ.
Alvarez, Jose — Florida Atlantic Univ.
Sinisterra, Armando Jose — Florida Atlantic Univ.
von Ellenrieder, Karl — Florida Atlantic Univ.
Dhanak, Manhar — Florida Atlantic Univ.
Shah, Brual — Univ. of Maryland
Svec, Petr — Univ. of Maryland, Coll. Park
Gupta, Satyandra — Univ. of Maryland

This article presents an experimental assessment of an Unmanned Surface Vehicle (USV) executing an approach behavior to several stationary targets in an obstacle field. A lattice-based trajectory planner is developed with a priori knowledge of the vehicle characteristics. In parallel, a low-level controller is developed for the vehicle using a proportional control law. These systems are integrated on the USV control system using the message passing system known as Lightweight Communications and Marshalling (LCM). Using LCM, the filtered vehicle-state information from the onboard sensors is passed to the planner, which returns a least-cost, dynamically feasible trajectory for achieving the ascertained goal. The system was tested in a 750 m by 150 m area of the US Intracoastal Waterway in South Florida in the presence of wind and wave disturbances to characterize its effectiveness in a real-world scenario. It was found that the vehicle was able to replicate behavior as predicted in simulations when navigating around obstacles with approach distance to each target being favorably lower than the user-defined limit. Owing to the fact that the USV uses differential thrust for steering, the vehicle tracked the planned trajectories better at lower speeds.

MoCT4	Paul Brest West
Control of Building Energy Systems (Invited session)	
Chair: Rasmussen, Bryan	Texas A&M Univ.
Co-Chair: Chen, Dongmei	The Univ. of Texas at Austin
Organizer: Rasmussen, Bryan	Texas A&M Univ.
Organizer: Chen, Dongmei	The Univ. of Texas at Austin

16:00-16:20 MoCT4.1

Optimal Control of Office Plug-Loads for Commercial Building Demand Response (I), pp. 806-813

Arnold, Daniel — Univ. of California Berkeley
Sankur, Michael — Univ. of California, Berkeley
Auslander, David — Univ. of California Berkeley

While historically the electrical energy resource a commercial building may utilize during a Demand Response (DR) event has been limited to building HVAC and/or lighting systems, enabling technologies such as smart power strips (SPSs) and Energy Information Gateways (EIGs) have made distributed control over commercial office plug loads a reality. This paper investigates coordinated optimal control over plug loads in a commercial building during a DR event. Control over local office plug loads is accomplished via the use of a software entity, the Energy Information Gateway, which employs a binary integer linear program to determine which loads are shed. Individual EIGs are managed by another piece of software, the Central Building Controller (CBC), which can adjust parameters in the individual EIG optimal control algorithm. The proposed control structure is tested via the EIGs managing physical appliances in an actual office, and in simulations of the CBC managing virtual Gateways.

16:20-16:40 MoCT4.2

Dynamic Energy Management of a Residential Energy Eco-System (I), pp. 814-823

Muratori, Matteo — The Ohio State Univ.
Chang, Chin-Yao — The Ohio State Univ.
Rizzoni, Giorgio — Ohio State Univ.
Zhang, Wei — The Ohio State Univ.

In this paper, we present a dynamic energy management framework for a generic residential eco-system. The proposed automated management framework is based on highly-resolved personal energy consumption models developed using a novel bottom-up approach that quantifies consumer energy use behaviors. The incorporation of stochastic consumer behaviors provides more accurate estimation of the actual amount of available controllable resources in the population, and hence enables better interactions with the grid. The energy management problem is solved by use of a stochastic dynamic programming (DP) algorithm that considers household members' behavior, as predicted by the highly-resolved personal energy consumption model, and manages controllable appliances and plug-in electric vehicles charging. The algorithm is flexible enough to accommodate diverse costs functions, aimed at simulating different scenarios.

16:40-17:00 MoCT4.3

A Model-Based Predictive Control Approach for a Building Cooling System with Ice Storage (I), pp. 824-832

Raissi Dehkordi, Vahid — Natural Res. Canada
Candanedo, José — Natural Res. Canada

This paper presents a model predictive control (MPC) algorithm designed for the cooling system of a small commercial building under a time-dependent electricity price profile. The proposed approach

includes a problem formulation in terms of cooling power, a variable-length prediction horizon and the consideration of the equipment duty cycle as a constraint in the optimization algorithm. The cooling system is equipped with an ice bank for thermal energy storage. A simple linear building thermal model is used to calculate the required amount of cooling power to maintain thermal comfort. The MPC algorithm uses this information to find the optimal operating points for the chiller and the ice bank to minimize the electric energy cost. The results of the MPC algorithm are compared against those of the reactive rule-based control algorithm currently in use in the building.

17:00-17:20	MoCT4.4

Pareto Optimal Setpoints for HVAC Networks Via Iterative Nearest Neighbor Communication (I), pp. 833-842

Elliott, Matthew	Texas A&M Univ.
Bay, Christopher	Texas A&M Univ.
Rasmussen, Bryan	Texas A&M Univ.

HVAC systems in large buildings frequently feature a network topology wherein the outputs of each dynamic subsystem act as disturbances to other subsystems in a well-defined local neighborhood. The distributed optimization technique presented in this paper leverages this topology without requiring a centralized optimizer or widespread knowledge of the interaction dynamics between subsystems. Each subsystem's optimizer communicates to its neighbors its calculated optimum setpoint, as well as the costs imposed by the neighbor's calculated setpoints. By judicious construction of the cost functions, all of the cost information is propagated through the network, allowing a Pareto optimal solution to be reached. The novelty of this approach is that communication between all plants is not necessary to achieve a global optimum, and that changes in one controller do not require changes to all controllers in the network. Proofs of Pareto optimality are presented, and convergence under the approach is demonstrated with a numerical and experimental example.

17:20-17:40	MoCT4.5

Optimal Subcooling in Vapor Compression Systems Via Extremum Seeking Control (I), pp. 843-852

Koeln, Justin	Univ. of Illinois at Urbana Champaign
Alleyne, Andrew G.	Univ. of Illinois at Urbana-Champaign

Building systems constitute a significant portion of the overall energy consumed each year in the U.S., and a large portion of this energy is used by air-conditioning systems. Therefore, the efficiency of these systems is important. This paper presents a method to increase system efficiency using an alternative system architecture for vapor compression systems. This architecture creates an additional degree of freedom which allows for independent control of condenser subcooling. It is found that there exists a non-zero subcooling that maximizes system efficiency; however, this optimal subcooling can change with different operating conditions. Thus, extremum seeking control is applied to find and track the optimal subcooling using only limited information of the system. In a simulation case study, a 10% reduction in energy consumption is reported when using the alternative system architecture and extremum seeking control when compared to a conventional system configuration.

17:40-18:00	MoCT4.6

Decentralized Feedback Control of Smart Lighting Systems (I), pp. 853-862

Afshari, Sina	Rensselaer Pol. Inst.
Mishra, Sandipan	Renssealer Pol. Inst.

This paper presents a framework for designing controllers for self-commissioning smart lighting systems with plug-and-play capability. A class of decentralized feedback control methods is proposed for this purpose. Theoretical results for stability and convergence of the proposed algorithms are presented. Further, an automated self-commissioning algorithm is designed to minimize re-identification efforts necessary for the decentralized controller in case of a change in the lighting configuration (e.g. the addition of a new fixture to an existing space). The implementation of this algorithm demonstrates significant reduction in the commissioning effort. Finally, centralized, decentralized and consensus-based control algorithms are implemented on an experimental adaptive lighting testbed. The performance of the decentralized methods is shown to be comparable to that of the centralized controller.

MoCT5	Tent B

Instrumentation and Characterization in Bio-Systems (Invited session)

Chair: Hahn, Jin-Oh	Univ. of Maryland
Co-Chair: Ashrafiuon, Hashem	Villanova Univ.
Organizer: Hahn, Jin-Oh	Univ. of Maryland
Organizer: Ashrafiuon, Hashem	Villanova Univ.
Organizer: Nataraj, C.	Villanova Univ.
Organizer: Asada, H. Harry	Massachusetts Inst. of Tech.

16:00-16:20	MoCT5.1

A Handheld Noninvasive Sensing Method for the Measurement of Compartment Pressures (I), pp. 863-869

Flegel, Christopher	Univ. of Minnesota
Singal, Kalpesh	Univ. of Minnesota
Rajamani, Rajesh	Univ. of Minnesota

Compartment syndrome is a major concern in cases of extremity trauma, which occur in over 70% of military combat casualty. Without treatment, compartment syndrome can lead to paralysis, loss of limb, or death. This paper focuses on the development of a handheld sensor that can be used for the non-invasive diagnosis of compartment syndrome. Analytical development of the sensing principle is first presented in which a relation is obtained between the pressure in a fluid compartment and the stiffness experienced by a handheld probe pushing on the compartment. Then a handheld sensor that can measure stiffness of an object without requiring the use of any inertial reference is presented. The handheld sensor consists of an array of three miniature force-sensing spring loaded pistons placed together on a probe. The center spring is chosen to be significantly stiffer than the side springs. The ratio of forces between the stiff and soft springs is proportional to the stiffness of the soft object against which the probe is pushed. Small mm-sized magnets on the pistons and magnetic field measurement chips are used to measure the forces in the individual pistons. Experimental results are presented using an in-vitro test rig that replicates a fluid pressure compartment. The sensor is shown to measure pressure accurately with a resolution of 0.1 psi over the range 0.75 psi to 2.5 psi.

16:20-16:40	MoCT5.2

Output-Boundary Regulation: High-Speed AFM Imaging Application (I), pp. 870-879

Boekfah, Arom	Univ. of Washington
Devasia, Santosh	Univ. of Washington

This article addresses output-boundary regulation for high-scan-frequency Atomic Force Microscope (AFM) imaging of soft samples. The main contribution of this article is to use the causal inverse for nonminimum phase systems to rapidly transition an output away from a specified boundary whenever the output approaches the boundary due to unknown disturbances. The proposed feedforward-based control technique overcomes both: (i) lack of preview information of the disturbances; and (ii) performance limitations of feedback-based control methods for nonminimum-phase systems. Simulation results for an example AFM are presented to illustrate the approach.

16:40-17:00	MoCT5.3

A Microscale Piezoresistive Force Sensor for Nanoindentation of Biological Cells and Tissues (I), pp. 880-884

Pandya, Hardik	Univ. of Maryland, Coll. Park
Kim, Hyun Tae	Mechanical Engineering, Univ. of Maryland, Coll. Park
Desai, Jaydev	Univ. of Maryland, Coll. Park

We present the design and fabrication of a Micro-Electro- Mechanical Systems based piezoresistive cantilever force sensor as a potential candidate for micro/nano indentation of biological specimens such as cells and tissues.The fabricated force sensor consists of a silicon cantilever beam with a p-type piezoresistor and a cylindrical probing tip made from SU-8 polymer. One of the key features of the sensor is that a standard silicon wafer is used to make silicon-on-insulator (SOI), thereby reducing the cost of fabrication. To make SOI from standard silicon wafer the silicon film was sputtered on an oxidized silicon wafer and annealed at 1050 ^{0}C so as to obtain polycrystalline silicon. The sputtered silicon layer was used to fabricate the cantilever beam. The as-deposited and annealed silicon films were experimentally characterized using X-ray diffraction (XRD) and Atomic Force Microscopy (AFM). The annealed silicon film was polycrystalline with a low surface roughness of 3.134 nm (RMS value).

17:00-17:20	MoCT5.4

Real-Time Image Processing for Locating Veins in Mouse Tails (I), pp. 885-891

Chang, Yen-Chi	Univ. of California, Los Angeles
Berry-Pusey, Brittany	Crump Insitute for Molecular Imaging Univ. of California, L
Tsao, Tsu-Chin	Univ. of California Los Angeles
Chatziioannou, Arion	Crump Insitute for Molecular Imaging, Univ. of California L

This paper develops an efficient vision-based real-time vein detection algorithm for preclinical vascular insertions. Mouse tail vein injections perform a routine but critical step in most preclinical applications. Compensating for poor manual injection stability and high skill requirements, Vascular Access System (VAS) has been developed so a trained technician can manually command the system to perform needle insertions and monitor the operation through a near-infrared camera. However, VAS' vein detection algorithm requires much computation and is, therefore, difficult to reflect the real-time tail movement during an insertion. Furthermore, the detection performance is of-ten disturbed by tail hair and skin pigmentation. In this work, an effective noise filtering algorithm is proposed based on con-vex optimization. Effectively eliminating false-positive detections and preserving cross-sectional continuity, this algorithm provides vein detection results approximately every 200 ms at the presence of tail hair and skin pigmentation. This developed real-time tail vein detection method is able to capture the tail movement during insertion, therefore allow for the development of an automated Vascular Access System (A-VAS) for preclinical injections.

17:20-17:40	MoCT5.5

Towards the Development of Optogenetically-Controlled Skeletal Muscle Actuators (I), pp. 892-896

Kim, Hyeonyu	MIT
Neal, Devin	MIT
Asada, H. Harry	Massachusetts Inst. of Tech.

Engineered skeletal muscle tissue has the potential to be used as dual use actuator and stress-bearing material providing numerous degrees of freedom and with significant active stress generation. To exploit the potential features, however, technologies must be established to generate mature muscle strips that can be controlled with high fidelity. Here, we present a method for creating mature 3-D skeletal muscle tissues that contract in response to optical activation stimuli. The muscle strips are fascicle-like, consisting of several mm-long multi-nucleate muscle cells bundled together. We have found that applying a tension to the fascicle-like muscle tissue promotes maturation of the muscle. The fascicle-like muscle tissue is controlled with high spatiotemporal resolution based on optogenetic coding. The mouse myoblasts C2C12 were transfected with Channelrhodopsin-2 to enable light (~470 nm) to control muscle contraction. The 3D muscle tissue not only twitches in response to an impulse light beam, but also exhibits a type of tetanus, a prolonged contraction of continuous stimuli, for the first time. In the following, the materials and culturing method used for 3D muscle generation is presented, followed by experimental results of muscle constructs and optogenetic control of the 3D muscle tissue.

17:40-18:00	MoCT5.6

Control of Highly Organized Nanostructures in Microchannels Using Nanoliter Droplets (I), pp. 897-902

Choi, Eunpyo	Sogang Univ.
Kwon, Kilsung	Sogang Univ.
Chang, Hyung-kwan	Sogang Univ.
Kim, Daejoong	Sogang Univ.
Park, Jungyul	Sogang Univ.

In this study, we introduce a novel method for control of self-organization of nanoparticles in microchannels using the control of nanoliter droplets and show its useful applications. By controlling capillary force and evaporation process, nanoparticles can be assembled at the desired area and they can be used from nanoporous membranes to biosensor itself. As the biosensor applications, biologically inspired humidity sensor and IgG antibody detector were developed. They can recognize the target materials by the change of visual color without using any fluorescent probe and external electrical power source. These highly organized nanoparticles also induce the unique nanoelectrokinetics, which open new application fields such as such as separation, filtering, accumulation, and analysis of biomolecules, energy generation, and optofluidic system. Among them, we introduce two techniques that are diffuse based chemical gradient generation and sea water desalination.

MoCT6	Room 134

Control, Monitoring, and Energy Harvesting of Vibratory Systems: Active Vibration Control-3 (Invited session)

Chair: Tang, Jiong	Univ. of Connecticut
Co-Chair: Nishimura, Hidekazu	Keio Univ.
Organizer: Zuo, Lei	Stony Brook Univ. - SUNY
Organizer: Tang, Jiong	Univ. of Connecticut
Organizer: Sipahi, Rifat	Northeastern Univ.
Organizer: Caruntu, Dumitru	Univ. of Texas Pan American
Organizer: Nishimura, Hidekazu	Keio Univ.
Organizer: Kajiwara, Itsuro	Hokkaido Univ.

16:00-16:20	MoCT6.1

Unknown Disturbance Estimator Design for Non-Minimum Phase Plants Using Parallel Feed-Forward Model (I), pp. 903-910

Chida, Yuichi	Shinshu Univ.
Sekiguchi, Shota	Shinshu Univ.
Kobayashi, Hiroyuki	Shinshu Univ.
Ikeda, Yuichi	Shinshu Univ.

A novel design method of an unknown disturbance observer for non-minimum phase plants is proposed in the present paper. In order to improve the estimation performances, a virtual augmented plant is introduced by adding a parallel model to the non-minimum phase real plant. And the parallel model is designed such that the virtual augmented model becomes the minimum phase. Then, it is possible to design the unknown disturbance estimator for the minimum phase plant not for the non-minimum phase plant, so it is possible to

improve the estimation performances. In this case, it is important to clarify the relationship between the unknown disturbance estimation signal for the real plant and the virtual augmented plant. In the present paper, a re-construct method of the unknown disturbance estimation signal from the virtual plant to the real plant is proposed and the parallel model design method is also shown. The effectiveness of the proposed method is verified by numerical simulations for several mechanical vibration systems. The results show that the proposed method can improve estimation performances in comparison with conventional methods.

16:20-16:40 MoCT6.2

An Experimental Study on Balancing Tasks of Human Subjects in Cooperation with Invisible Artificial Partners (I), pp. 911-919

Matsumoto, Shigeki Utsunomiya Univ.
Yoshida, Katsutoshi Utsunomiya Univ.

This paper studies coupled balancing tasks based on coupled inverted pendula (CIP) framework. We experimentally investigate the cooperative balancing task on a virtual CIP model, performed by a pair of an invisible artificial controller and a human subject, where experimental participants were not allowed to watch the movement of the artificial partner during experiments. The experimental result on Lyapunov exponents implies that the human subject seems to try to make the artificial controller neutrally stable as well as the visible case in our previous study. Therefore, the result implies that the visual feedback from the balancing state of the artificial partner may not be related to the dynamical property of human.

16:40-17:00 MoCT6.3

Precision Control through Vibration Suppression in Piezoelectric Stepper Response (I), pp. 920-928

Wilcox, Scott U. of Washington
Devasia, Santosh Univ. of Washington

The main contribution of this article is to show that, when compared to single actuator steppers, the response of multi-actuator steppers can be significantly less oscillatory and these reduced oscillations allow for higher precision velocity control of a motion stage. Moreover, it is shown that the resulting motion of the motion stage is stable using a Poincare-map approach.

17:00-17:20 MoCT6.4

Formulation for Interaction Analysis between Continuous and Discrete Structures Subject to Moving Loads Applied to Turning (I), pp. 929-936

Madariaga, Jon IK4-Tekniker
Tsao, Tsu-Chin Univ. of California Los Angeles
Ruiz, Ismael IK4-Tekniker

A control oriented formulation of continuous structures interacting with moving and/or fixed structures is presented. Machining of long parts in a lathe is presented in order to illustrate the methodology. The system is time-varying in nature due to the movement of the cutting tool during the machining process. However the invariant part corresponding to the structure dynamics (tool and workpiece) and the time varying part corresponding to the movement of the cutting point can be separated. The link between the two is given by the eigenfunctions relating the output of the dynamic part with the actual displacement within the workpiece continuum. This splitted formulation allows modular design approaches, facilitating the inclusion and analysis of further elements such as flexible supports and/or allowing direct modifications of the characteristics of the different structural elements individually (considered vibration modes, etc.). For the presented turning example the implications of workpiece flexibility and the inclusion of flexible supports at different locations on regenerative chatter stability are also discussed.

17:20-17:40 MoCT6.5

Adaptive Control of Acoustic Waves in Flexible Structure (I), pp. 937-943

Ji, Chunhua Univ. of Connecticut
Gao, Robert Univ. of Connecticut
Fan, Zhaoyan Univ. of Connecticut
Liang, Kenneth Schlumberger-Doll Res. Center
Pabon, Jahir Schlumberger-Doll Res. Center

An active cascading control method for wave propagating along a flexible structure is proposed, developed and experimentally evaluated on a hanging steel beam. To ensure satisfactory performance, multiple control points are set up along the tool wave propagation path. A multi-channel feed forward control algorithm was developed to suppress both the head wave from the transmitter and the coupling waves from the wave cancelling actuators. An adaptive IIR filtering approach was taken to extract system dynamics and avoid mode uncertainty/truncation under high frequencies. To determine the optimal controller weights and minimize wave energy, an NLMS adaptive algorithm was realized, based on the IIR models. An experimental setup, composed of a steel beam as the wave propagation medium and 5 cascading control stations, was developed. Experimental results have shown that, under both wide and narrow band width conditions, wave energy suppression of over 98.7% has been achieved

17:40-18:00 MoCT6.6

Fine Structure of Pareto Front of Multi-Objective Optimal Feedback Control Design (I), pp. 944-949

Sun, Jian-Qiao UC Merced

Recently, we have proposed the simple cell mapping method (SCM) for global solutionsof multiobjective optimization problems (MOPs). We have applied the SCM method to the multi-objective optimal time domain design of PID control gains for linear systems to simultaneously minimize the overshoot, peak time and integrated absolute tracking error of the closed-loop step response. The SCM method can efficiently obtain the Pareto set and Pareto front globally, which represent the optimal control gains and performance measures, respectively. The Pareto set and Pareto front contain a complete set of control designs with various compromises in the tracking performance, and give the system designer a much wider range of choices and flexibility. Furthermore, we have discovered a fine structure of the Pareto front of the MOP solution, which was notseen before in the literature. In this paper, we further examine the implication of the fine structure with regard to the vibration control design and expected performance of the controller, and compare our findings with the dominant method in MOP studies, i.e. the genetic algorithm.6

MoCT7 Room 138

Nonlinear Estimation and Control (Contributed session)

Chair: Djurdjanovic, Dragan Univ. of Texas
Co-Chair: Bevly, David Auburn Univ.

16:00-16:20 MoCT7.1

Robust Observer Design for Lipschitz Nonlinear Systems with Parametric Uncertainty, pp. 950-959

Wang, Yan Auburn Univ.
Bevly, David Auburn Univ.

his paper discusses optimal and robust observer design for the Lipschitz nonlinear systems. The stability analysis for the Lure problem is first reviewed. Then, a two-DOF nonlinear observer is proposed so that the observer error dynamic model can be transformed to an equivalent Lure system. In this framework, the difference of the nonlinear parts in the vector fields of the original system and observer is modeled as a nonlinear memoryless block that is covered by a multivariable sector condition or an equivalent semi-algebraic set defined by a quadratic polynomial inequality. Then, a sufficient condition for asymptotic stability of the observer error dynamics is formulated in terms of the feasibility of polynomial matrix inequalities (PMIs), which can be solved by Lasserre's moment relaxation. Furthermore, various quadratic performance criteria, such as H2 and H_infinity, can be easily incorporated in this framework. Finally, a parameter adaptation algorithm is introduced to cope with the parameter uncertainty.

16:20-16:40	MoCT7.2

Robust Disturbance Rejection for a Class of Nonlinear Systems Using Disturbance Observers, pp. 960-967

El Shaer, Ahmed H.	LineStream Tech.
Bajodah, Abdulrahman	King Abdulaziz Univ.

This paper is concerned with disturbance rejection performance in single-input single-output (SISO) nonlinear systems that are described by uncertain linear dynamics and bounded nonlinearities. First, the nonlinear terms are transformed into an equivalent bounded disturbance at the output of a linear system. Then, a disturbance observer (DOB) is added to the closed loop to achieve robust disturbance rejection. The DOB design is formulated as an extended Luenberger observer having internal dynamics with at least an eigenvalue at the origin. The synthesis of a (sub)optimal DOB is carried out by solving multi-objective <i>H_{∞</i>}-sensitivity optimization. The design approach is applied to an inverted pendulum with actuator backlash. Closed loop response shows that tracking performance is indeed greatly enhanced with the DOB.

16:40-17:00	MoCT7.3

Model-Predictive Control and Closed-Loop Stability Considerations for Nonlinear Plants Described by Local ARX-Type Models, pp. 968-977

Cholette, Michael	Queensland Univ. of Tech.
Djurdjanovic, Dragan	Univ. of Texas

In this paper, a Model-predictive Control (MPC) method is detailed for the control of nonlinear systems with stability considerations. It will be assumed that the plant is described by a local input/output ARX-type model, with the control potentially included in the premise variables, which enables the control of systems that are nonlinear in the control input. Additionally, for the case of set point regulation, a suboptimal controller is derived which enables finite-iteration termination of the iterative nonlinear optimization procedure that is used to determine the stabilizing control signal.

17:00-17:20	MoCT7.4

Nonparametric Identification of Hammerstein Systems Using Orthogonal Basis Functions As Ersatz Nonlinearities, pp. 978-985

Aljanaideh, Khaled	Univ. of Michigan
Bernstein, Dennis S.	Univ. of Michigan

In this paper, we present a technique for estimating the input nonlinearity of a Hammerstein system by using multiple orthogonal ersatz nonlinearities. Theoretical analysis shows that by replacing the unknown input nonlinearity by an ersatz nonlinearity, the estimates of the Markov parameters of the plant are correct up to a scalar factor, which is related to the inner product of the true input nonlinearity and the ersatz nonlinearity. These coefficients are used to construct and estimate the true nonlinearity represented as an orthogonal basis expansion. We demonstrate this technique by using a Fourier series expansion as well as orthogonal polynomials. We show that the kernel of the inner product associated with the orthogonal basis functions must be chosen to be the density function of the input signal.

17:20-17:40	MoCT7.5

An Adaptive Control Method with Low-Resolution Encoder, pp. 986-995

Zhang, Zhenyu	Western Digital Corp.
Olgac, Nejat	Univ. of Connecticut

An adaptive control methodology with a low-resolution encoder feedback is presented for a biomedical application, the Ros-Drill (Rotationally Oscillating Drill). It is developed primarily for ICSI (Intra-Cytoplasmic Sperm Injection) operations, with the objective of tracking a desired oscillatory motion at the tip of a microscopic glass pipette. It is an inexpensive set-up, which creates high-frequency (higher than 500 Hz) and small-amplitude (around 0.2 deg) rotational oscillations at the tip of an injection pipette. These rotational oscillations enable the pipette to drill into cell membranes with minimum biological damage. Such a motion control procedure presents no particular difficulty when it uses sufficiently precise motion sensors. However, size, costs and accessibility of technology on the hardware components severely constrain the sensory capabilities. Consequently the control mission and the trajectory tracking are adversely affected. This paper presents a dedicated novel adaptive feedback control method to achieve a satisfactory trajectory tracking capability. We demonstrate via experiments that the tracking of the harmonic rotational motion is achieved with desirable fidelity.

17:40-18:00	MoCT7.6

Asymptotic Stability Method for PID Controller Tuning in a Backhoe Machine, pp. 996-1003

Mastalli, Carlos Eduardo	Simon Bolivar Univ.
Ralev, Dimitar	Simon Bolivar Univ.
Certad, Novel	Simon Bolivar Univ.
Fernandez, Gerardo	Simon Bolivar Univ.

This paper presents the modeling and study of dynamic behavior of a backhoe machine for tuning of PID controller. The tuning procedure of PID controller is performed, in detailed, for the case of a typical operation, digging a foundation and truck loading. This tuning procedure guarantee the local asymptotic stability in the sense of Lyapunov of origin of the closed loop equation of PID controller. Besides the tuning procedure requires the knowledge of certain properties of dynamic model, which are dependent on the desired trajectory. Finally it is demonstrated that this tuning procedure proves to be effective, and also robust in the execution of other tasks performed by the backhoe machine.

Technical Program for Tuesday October 22, 2013

TuAT1	Paul Brest East
Vehicle Dynamics and Control (Contributed session)	
Chair: Wang, Junmin	The Ohio State Univ.
Co-Chair: Ayalew, Beshah	Clemson Univ.

10:15-10:35 TuAT1.1

Network Control of Vehicle Lateral Dynamics with Control Allocation and Dynamic Message Priority Assignment, pp. 1004-1013

Shuai, Zhibin — Ohio State Univ.
Zhang, Hui — The Ohio State Univ.
Wang, Junmin — The Ohio State Univ.
Li, Jianqiu — Tsinghua Univ.
Ouyang, Minggao — Tsinghua Univ.

In this paper we study the lateral motion control and torque allocation for four-wheel-independent-drive electric vehicles (4WID-EVs) with combined active front steering (AFS) and direct yaw moment control (DYC) through in-vehicle networks. It is well known that the in-vehicle networks and x-by-wire technologies have considerable advantages over the traditional point-to-point communications, and bring great strengths to 4WID-EVs. However, there are also bandwidth limitations which would lead to message time delays in network communication. We propose a method on effectively utilizing the limited bandwidth resources and attenuating the adverse influence of in-vehicle network-induced time delays, based on the idea of dynamic message priority assignment according to the vehicle states and control signals. Simulation results from a high-fidelity vehicle model in CarSim® show that the proposed vehicle lateral control and torque allocation algorithm can improve the 4WID-EV lateral motion control performance, and the proposed message priority dynamic assignment algorithm can significantly reduce the adverse influence of the in-vehicle network-induced time delays.

10:35-10:55 TuAT1.2

Adaptive Traction Control for Non-Rigid Tire-Wheel Systems, pp. 1014-1023

Adcox, John — Clemson Univ.
Ayalew, Beshah — Clemson Univ.

The designs of commercial Anti-Lock Braking Systems often rely on assumptions of a torsionally rigid tire-wheel system. However, variations in tire/wheel technologies have resulted in lower torsional stiffnesses that cannot be captured well using these rigid wheel assumptions. This paper presents an adaptive nonlinear controller based on a model that incorporates sidewall flexibility, and transient & hysteretic tread-ground friction effects. The sidewall stiffness and damping and as well as tread parameters are assumed to be unknown and subsequently estimated through a set of gradient-based adaptation laws. A virtual damper is introduced via a backstepping controller design to address difficulties associated with tires with low torsional damping.

10:55-11:15 TuAT1.3

Vehicle Roll Stabilization Enhancement Using a Variable Stiffness Architecture: Kinematic Control, pp. 1024-1033

Anubi, Olugbenga — Univ. of Florida
Crane, Carl — Univ. of Florida

A variable stiffness architecture is used in the suspension system to counteract the body roll moment, thereby enhancing the roll stability of the vehicle. The variation of stiffness concept uses the ``reciprocal actuation" to effectively transfer energy between a vertical traditional strut and a horizontal oscillating control mass, thereby improving the energy dissipation of the overall suspension. The lateral dynamics of the system is developed using a bicycle model. The accompanying roll dynamics are also developed and validated using experimental data. The positions of the left and right control masses are optimally allocated to reduce the effective body roll and roll rate. Simulation results show that the resulting variable stiffness suspension system has more than 50% improvement in roll response over the traditional constant stiffness counterparts. The simulation scenarios examined is the fishhook maneuver.

11:15-11:35 TuAT1.4

Cooperative Trajectory Planning for Automated Farming, pp. 1034-1041

Remeikas, Charles — Univ. of Central Florida
Xu, Yunjun — Univ. of Central Florida
Jayasuriya, Suhada — Univ. of Central Florida

Many agricultural tasks, such as harvesting, are labor intensive. With the interests in autonomous farming, a method to rapidly generate trajectories for agricultural robots satisfying different realistic constraints becomes necessary. A hierarchical cooperative planning method is studied in this paper for a group of agricultural robots with a low computational cost. Two parts are involved in the method: once a reconfiguration event is confirmed, all the possible formation configurations will be evaluated and ranked according to their feasibility and performance index; a local pursuit strategy based cooperative trajectory planning algorithm is designed to generate optimal cooperative trajectories for robots to achieve and maintain their desired formation. To help reduce the computation cost associated with the cooperative planning algorithm, early termination conditions are proposed. The capabilities of the proposed cooperative planning algorithm are demonstrated in a simple citrus harvesting problem.

11:35-11:55 TuAT1.5

The Role of Model Fidelity in Model Predictive Control Based Hazard Avoidance in Unmanned Ground Vehicles Using LIDAR Sensors, pp. 1042-1051

Liu, Jiechao — Univ. of Michigan
Jayakumar, Paramsothy — U.S. Army RDECOM-TARDEC
Overholt, James L. — U.S. Army RDECOM-TARDEC
Stein, Jeffrey L. — Univ. of Michigan
Ersal, Tulga — Univ. of Michigan

Unmanned ground vehicles (UGVs) are gaining importance and finding increased utility in both military and commercial applications. Although earlier UGV platforms were typically exclusively small ground robots, recent efforts started targeting passenger vehicle and larger size platforms. Due to their size and speed, these platforms have significantly different dynamics than small robots, and therefore the existing hazard avoidance algorithms, which were developed for small robots, may not deliver the desired performance. The goal of this paper is to present the first steps towards a model predictive control (MPC) based hazard avoidance algorithm for large UGVs that accounts for the vehicle dynamics through high fidelity models and uses only local information about the environment as provided by the onboard sensors. Specifically, the paper presents the MPC formulation for hazard avoidance using a light detection and ranging (LIDAR) sensor and applies it to a case study to investigate the impact of model fidelity on the performance of the algorithm, where performance is measured mainly by the time to reach the target point. Towards this end, the case study compares a 2 degrees-of-freedom (DoF) vehicle dynamics representation to a 14 DoF representation as the model used in MPC. The results show that the 2 DoF model can perform comparable to the 14 DoF model if the safe steering range is established using the 14 DoF model rather than the 2 DoF model itself. The conclusion is that high fidelity models are needed to push autonomous vehicles to their limits to increase their performance, but simulating the high fidelity models online within the MPC may not be as critical as using them to establish the safe control input limits.

11:55-12:15 TuAT1.6

*Vehicle Dynamic Estimation Based on Coupling Unscented Particle Filter**

Lin, Fen — Nanjing Univ. of Aeronautics and

Astronautics

A critical component of vehicle dynamic control systems is the accurate and real time knowledge of vehicle key states when running on road. Sometimes the results of estimation are affected by inaccurate vehicle parameters. Aiming at the problem and defects of the former Kalman Filter based estimation method, a new vehicle state estimator is proposed. A nonlinear 3-DOF vehicle dynamics system in which contains inaccurate model parameters is established. Then a coupling unscented particle filter (CUPF) based algorithm is proposed. In the algorithm two unscented Particle Filter run at the same time, states estimation and parameters identification update each other. The results of simulation and experiment demonstrate that the proposed algorithm has higher state estimation accuracy, also has good capability to revise model parameters.

TuAT2	Room 123
Cooperative and Networked Control (Contributed session)	
Chair: Milutinovic, Dejan	Univ. of California Santa Cruz
Co-Chair: Patel, Rushabh	Univ. of California Santa Barbara

10:15-10:35 TuAT2.1

The Dubins Traveling Salesperson Problem with Stochastic Dynamics, pp. 1052-1058

Anderson, Ross	Univ. of California, Santa Cruz
Milutinovic, Dejan	Univ. of California Santa Cruz

Motivated by applications in which a nonholonomic robotic vehicle should sequentially hit a series of waypoints in the presence of stochastic drift, we formulate a new version of the Dubins vehicle traveling salesperson problem. In our approach, we first compute the minimum expected time feedback control to hit one waypoint based on the Hamilton-Jacobi-Bellman equation. Next, minimum expected times associated with the control are used to construct a traveling salesperson problem based on a waypoint hitting angle discretization. We provide numerical results illustrating our solution and analyze how the stochastic drift affects the solution.

10:35-10:55 TuAT2.2

Hybrid Particle Swarm – Tabu Search Optimization Algorithm for Parameter Estimation, pp. 1059-1067

Sebastian, Anish	Idaho State Univ.
Schoen, Marco	Idaho State Univ.

A hybrid intelligent algorithm is proposed. The algorithm utilizes a particle swarm and a Tabu search algorithm. Swarm based algorithms and single agent based algorithms each, have distinct advantages and disadvantages. The goal of the presented work is to combine the strengths of the two different algorithms in order to achieve a more effective optimization routine. The developed hybrid algorithm is tailored such that it has the capability to adapt to the given cost function during the optimization process. The proposed algorithm is tested on a set of different benchmark problems. In addition, the hybrid algorithm is utilized for solving the estimation problem encountered for estimating the finger force output given a surface electromyogram (sEMG) signal at the input. This estimation problem is commonly encountered while developing a control system for a prosthetic hand.

10:55-11:15 TuAT2.3

Centroidal Area-Constrained Partitioning for Robotic Networks, pp. 1068-1072

Patel, Rushabh	Univ. of California Santa Barbara
Frasca, Paolo	Pol. di Torino
Bullo, Francesco	Univ. California at Santa Barbara

We consider the problem of optimal coverage with area-constraints in a mobile multi-agent system. For a planar environment with an associated density function, this problem is equivalent to dividing the environment into optimal subregions such that each agent is responsible for the coverage of its own region. In this paper, we design a continuous-time distributed policy which allows a team of agents to achieve a convex area-constrained partition of a convex workspace. Our work is related to the classic Lloyd algorithm, and makes use of generalized Voronoi diagrams. We also discuss practical implementation for real mobile networks. Simulation methods are presented and discussed.

11:15-11:35 TuAT2.4

Guaranteed Consensus in Radar Deception with a Phantom Track, pp. 1073-1079

Jayasuriya, Suhada	Univ. of Central Florida
Hajieghrary, Hadi	Univ. of Central Florida

Radar deception problems serve as a motivation to address the key issue of feasibility in trajectory planning for constrained dynamics of multi-agent systems. In a recent paper, Jayasuriya et al. presents an algorithm which claims to produce a dynamically feasible reference trajectory in real time. However, there was no proof provided for the proposed control strategy. This paper work through that algorithm; and, with a slight modification, provides some conditions on configuration parameters and the desired trajectory such that the proposed control guarantees consensus. These conditions dictate certain conditions on the initial configuration of the agents, consistent with the limitations on their actuators. Simulations support the idea that if the initial configuration along the final team goal is in admissible regions, the agents would always reach a consensus and maintain the formation.

11:35-11:55 TuAT2.5

Model-Based Compensation for Burst Message Loss in Wireless Networked Control Systems: Experimental Results, pp. 1080-1088

Godoy, Eduardo Paciencia	UNESP - São Paulo State Univ.
Scorzoni, Fernando	Univ. of São Paulo
Colon, Diego	São Paulo State Univ.
Porto, Arthur Jose Vieira	Univ. of São Paulo

A recent trend in networked control systems (NCSs) is the use of wireless networks enabling interoperability between existing wired and wireless systems. One of the major challenges in these wireless NCSs (WNCSs) is to overcome the impact of the message loss that degrades the performance and stability of these systems. Moreover, this impact is greater when dealing with burst or successive message losses. This paper discusses and presents the experimental results of a compensation strategy to deal with this burst message loss problem in which a NCS mathematical model runs in parallel with the physical process, providing sensor virtual data in case of packet losses. Running in real-time inside the controller, the mathematical model is updated online with real control signals sent to the actuator, which provides better reliability for the estimated sensor feedback (virtual data) transmitted to the controller each time a message loss occurs. In order to verify the advantages of applying this model-based compensation strategy for burst message losses in WNCSs, the control performance of a motor control system using CAN and ZigBee networks is analyzed. Experimental results led to the conclusion that the developed compensation strategy provided robustness and could maintain the control performance of the WNCS against different message loss scenarios.

11:55-12:15 TuAT2.6

Bandwidth Allocation of Networked Control Systems with Exponential Approximation, pp. 1089-1097

Dong, Jiawei	Texas A&M Univ.
Kim, Won-jong	Texas A&M Univ.

This paper investigates bandwidth allocation of networked control systems (NCSs) with nonlinear-programming techniques. The bandwidth utilization (BU) is defined in terms of sampling frequency. An exponential approximation is formulated to describe system performance versus the sampling frequencies. The optimal sampling frequencies are obtained by solving the approximation with

Karush-Kuhn-Tucker (KKT) conditions. Simulation and experimental results verify the effectiveness of the proposed approximation. The exponential approximation can minimize the BU so that the plants can be scheduled along with the system PIFs being optimized.

TuAT3	Tent A
Nonholonomic Systems (Contributed session)	
Chair: Kelly, Scott	Univ. of North Carolina at Charlotte
Co-Chair: Nersesov, Sergey G.	Villanova Univ.

10:15-10:35 TuAT3.1

Mechanics and Control of a Terrestrial Vehicle Exploiting a Nonholonomic Constraint for Fishlike Locomotion, pp. 1098-1102

Dear, Tony	Carnegie Mellon Univ.
Kelly, Scott	Univ. of North Carolina at Charlotte
Travers, Matthew	Carnegie Mellon
Choset, Howie	Carnegie Mellon Univ.

We present a novel mechanical system, the “landfish,” which takes advantage of a combination of articulation and a nonholonomic constraint to exhibit fishlike locomotion. We apply geometric mechanics techniques to establish the equations of motion in terms of the system's nonholonomic momentum and analyze the system's equilibrium properties. Finally, we demonstrate its locomotion capabilities under several controllers, including heading and joint velocity control.

10:35-10:55 TuAT3.2

Sliding Mode Coordination Control Design for Multiagent Systems, pp. 1103-1112

Ghasemi, Masood	Villanova Univ.
Nersesov, Sergey G.	Villanova Univ.

In this paper, we develop a coordination control technique for a group of agents described by a general class of underactuated dynamics. The objective is for the agents to reach and maintain a desired formation characterized by steady-state distances between the neighboring agents. We use graph theoretic notions to characterize communication topology in the network determined by the information flow directions and captured by the graph Laplacian matrix. Furthermore, using sliding mode control approach, we design decentralized controllers for individual agents that use only data from the neighboring agents which directly communicate their state information to the current agent in order to drive the current agent to the desired steady state. Finally, we show the efficacy of our theoretical results on the example of a system of wheeled mobile robots that reach and maintain the desired formation.

10:55-11:15 TuAT3.3

Energy-Based Limit Cycle Compensation for Dynamically Balancing Wheeled Inverted Pendulum Machines, pp. 1113-1120

Vasudevan, Hari	Yale Univ.
Dollar, Aaron	Yale Univ.
Morrell, John	Yale Univ.

In this paper we present an energy-based algorithm to minimize limit cycles in dynamically balancing wheeled inverted pendulum (IP) machines. Because the algorithm is not based on the numerical value of parameters, performance is robust and accounts for mechanical reconfiguration and wear. The effects of phenomena such as drive-train friction, rolling friction, backlash and sensor bandwidth are well known, causing either limit cycles or instabilities in IP balancing machines and yet compensation or control design to mitigate these effects are not well known. The effects of these non-linearities can be observed in the energy behavior of IP balancing machines, hence, as a broader goal we seek to establish an energy-based framework for the investigation of non-linearities in this class of machines. We successfully demonstrate the effectiveness of our algorithm on a two-wheeled IP balancing machine, ``Charlie'', developed in our laboratory. As an example we show a reduction in the amplitude of limit cycles by 95.9% in wheel angle and 89.8% in pitch over a 10 second period.

11:15-11:35 TuAT3.4

Trajectory Optimization for Nonholonomic Vehicles on Non-Flat Terrains Using Shooting and Collocation Methods, pp. 1121-1129

Chatzigeorgiou, Dimitris	MIT

In this paper we focus on the trajectory optimization problem for a specific family of robots; nonholonomic mobile robots. We study the particular case where such robots operate on smooth, non-flat terrains, i.e. terrains with large differences in elevation. Initially we present the governing equations of such robots and then study the trajectory optimization problem in order to solve for the optimal control policy. We test two different approaches for this problem, namely a shooting and a collocation method, for evaluating and optimizing a performance index.

11:35-11:55 TuAT3.5

Optimal Gait Design for Systems with Drift on SO(3), pp. 1130-1136

Travers, Matthew	Carnegie Mellon
Choset, Howie	Carnegie Mellon Univ.

Geckos that jump, cats that fall, and satellites that are inertially controlled fundamentally locomote in the same way. These systems are bodies in free flight that actively reorientate under the influence of conservation of angular momentum. We refer to such bodies as emph{inertial systems}. This work presents a novel control method for inertial systems with drift that combines geometric methods and computational control. In previous work, which focused on inertial systems starting from rest, a set of visual tools was developed that readily allowed one to design gaits. A key insight of this work was deriving coordinates, called minimum perturbation coordinates, which allowed the visual tools to be applied to the design of a wide range of motions. This paper draws upon the same insight to show that it is possible to approximately analyze the kinematic and dynamic contributions to net motion independently. This approach is novel because it uses geometric tools to support computational reduction in automatic gait generation on three-dimensional spaces.

11:55-12:15 TuAT3.6

Snakeboard Motion Planning with Local Trajectory Information, pp. 1137-1144

Dear, Tony	Carnegie Mellon Univ.
Hatton, Ross	Oregon State Univ.
Travers, Matthew	Carnegie Mellon
Choset, Howie	Carnegie Mellon Univ.

We address trajectory generation for the snakeboard, a system commonly studied in the geometric mechanics community. Our approach derives a solution using body coordinates and local trajectory information, leading to a more intuitive solution compared to prior work. The simple forms of the solution clearly show how they depend on local curvature and desired velocity profile, allowing for a description of some simple motion primitives. We readily propose techniques to navigate paths, including those with sharp corners, by taking advantage of the snakeboard's singular configuration, as well as discuss some implications of torque limits.

TuAT4	Paul Brest West
Estimation and Identification of Energy Systems (Invited session)	
Chair: Moura, Scott	UC San Diego
Co-Chair: Kim, Youngki	Univ. of Michigan
Organizer: McKahn, Denise A.	Smith Coll.
Organizer: Moura, Scott	UC San Diego

10:15-10:35	TuAT4.1

Estimating the Concentration Imbalance of a Vanadium Redox Flow Battery with Crossover Using a Constrained Extended Kalman Filter (I), pp. 1145-1151

Yu, Victor	The Univ. of Texas at Austin
Chen, Dongmei	The Univ. of Texas at Austin

One of the main issues with vanadium redox flow batteries is that vanadium ions travels across the membrane during operation which leads to a concentration imbalance and capacity loss after long-term cycling. Precise state of charge (SOC) monitoring allows the operator to effectively schedule electrolyte rebalancing and devise a control strategy to keep the battery running under optimal conditions. However, current SOC monitoring methods are too expensive and impractical to implement on commercial VRFB systems. Furthermore, physical models alone are neither reliable nor accurate enough to predict long-term capacity loss. In this paper, we present an application of using an extended Kalman filter (EKF) to estimate the total vanadium concentration in each half-cell by combining three voltage measurements and a state prediction model without crossover effects. Simulation results show that the EKF can accurately predict capacity loss for different crossover patterns over a few hundred cycles.

10:35-10:55	TuAT4.2

Modeling Heterogeneous Populations of Thermostatically Controlled Loads Using Diffusion-Advection PDEs (I), pp. 1152-1159

Moura, Scott	UC San Diego
Ruiz, Victor	Univ. of California, San Diego
Bendsten, Jan	Aalborg Univ.

This paper focuses on developing a partial differential equation (PDE)-based model and parameter identification scheme for heterogeneous populations of thermostatically controlled loads (TCLs). First, a coupled two-state hyperbolic PDE model for homogenous TCL populations is derived. This model is extended to heterogeneous populations by including a diffusive term, which provides an elegant PDE control-oriented model. Second, a novel parameter identification scheme is derived for the PDE model structure, which utilizes only boundary measurements and aggregated power measurements. Simulation results against a Monte Carlo model of a large TCL population demonstrate the usefulness of the approach. The proposed model and parameter identification scheme provide system critical information for advanced demand side management control systems.

10:55-11:15	TuAT4.3

Broad Frequency Vibration Energy Harvesting Control Approach Based on the Maximum Power Transfer Theorem (I), pp. 1160-1168

Pedchenko, Alexander	Vanderbilt Univ.
Barth, Eric J.	Vanderbilt Univ.

A control law for an electromagnetic vibration energy harvester is derived using the maximum power transfer theorem. Using regenerative electronics, the controller cancels the reactive portion of the harvester's impedance by eliminating the effect of mechanical inertia and stiffness elements, and the coil's electrical inductive element. The result is an energy harvester approach that captures more vibrational energy than a passive tuned harvester. It is shown that the controlled system acts like an infinite series of passive harvesters tuned to all frequency components within a certain frequency range. The control approach also avoids the delay and computational overhead of a Fast Fourier Transform as it does not require the explicit calculation of the excitation frequency. An experimental prototype harvester was built and characterized. The prototype's multi-domain dynamics were modeled using bond-graph techniques, and its behavior as a passive harvester was experimentally validated. The prototype's behavior under the proposed control method is simulated and compared to the passive case. It is shown that the proposed control method harvests more power for a range of excitation frequencies than the passive harvester.

11:15-11:35	TuAT4.4

Nonlinear State Estimation of Moving Boundary Heat Exchanger Models for Organic Rankine Cycle Waste Heat Recovery (I), pp. 1169-1177

Luong, David	Univ. of California, Los Angeles
Tsao, Tsu-Chin	Univ. of California Los Angeles

This paper presents results for nonlinear state estimation of a nonlinear, control-oriented Moving Boundary heat exchanger model derived from energy and mass conservation principles. The estimator design assumes pressure and temperature measurements typically available in waste heat recovery (WHR) applications. An Extended Kalman Filter (EKF) and a Fixed-Gain state estimator are developed for an open Organic Rankine Cycle (ORC). The ORC model assumes a nonlinear evaporator dynamic model connected to static expander and throttle valve models. Simulations show that the Fixed-Gain state estimator diverges when initial estimation error is present, and thus is not applicable for the nonlinear model. The EKF provides state estimates regardless of initial estimation error for both the Approximated and Full Jacobians used in the linearization update equations. The estimation error is slightly higher for the Approximated case only at the onset of mass flow rate changes, but shortly converge to zero in both cases. The results suggest the Approximated and Full Jacobians are valid for estimation of a nonlinear ORC in the presence of the examined transient inputs. Furthermore, the results are useful for state feedback control design and heat exchanger performance monitoring.

11:35-11:55	TuAT4.5

Maximum Power Estimation of Lithium-Ion Batteries Accounting for Thermal and Electrical Constraints, pp. 1178-1185

Kim, Youngki	Univ. of Michigan
Mohan, Shankar	Univ. of Michigan
Siegel, Jason B.	Univ. of Michigan
Stefanopoulou, Anna G.	Univ. of Michigan

Enforcement of constraints on the maximum deliverable power is essential to protect lithium-ion batteries from over-charge/discharge and overheating. This paper develops an algorithm to address the often overlooked temperature constraint in determining the power capability of battery systems. A prior knowledge of power capability provides dynamic constraints on currents and affords an additional control authority on the temperature of batteries. Power capability is estimated using a lumped electro-thermal model for cylindrical cells that has been validated over a wide range of operating conditions. The time scale separation between electrical and thermal systems is exploited in addressing the temperature constraint independent of voltage and state-of-charge (SOC) limits. Limiting currents and hence power capability are determined by a model-inversion technique, termed Algebraic Propagation (AP). Simulations are performed using realistic depleting currents to demonstrate the effectiveness of the proposed method.

11:55-12:15	TuAT4.6

Online Simultaneous State Estimation and Parameter Adaptation for Building Predictive Control (I), pp. 1186-1195

Maasoumy, Mehdi	UC Berkeley
Moridian, Barzin	Michigan Tech. Univ.
Razmara, Meysam	Michigan Tech. Univ.
Shahbakhti, Mahdi	Michigan Tech. Univ.
Sangiovanni Vincentelli, Alberto	Univ. OF CALIFORNIA BERKELEY

Model-based control of building energy offers an attractive way to minimize energy consumption in buildings. Model-based controllers require mathematical models that can accurately predict the behavior of the system. For buildings, specifically, these models are difficult to obtain due to highly time varying, and nonlinear nature of building dynamics. Also, model-based controllers often need information of all

states, while not all the states of a building model are measurable. In addition, it is challenging to accurately estimate building model parameters (e.g. convective heat transfer coefficient of varying outside air). In this paper, we propose a modeling framework for ``on-line estimation" of states and unknown parameters of buildings, leading to Parameter-Adaptive Building (PAB) model. Extended Kalman filter (EKF) and unscented Kalman filter (UKF) techniques are used to design the PAB model which simultaneously tunes the parameters of the model and provides an estimate for all states of the model. The proposed PAB model is tested with experimental data collected from a university building. Our results indicate that the new framework can accurately predict state and parameters of the building thermal model. The new modeling framework is expected to simplify design of a building predictive control by replacing nonlinear terms in a control model with linear adaptive parameters.

TuAT5	Tent B
Biomedical Robots and Rehabilitation (Contributed session)	
Chair: Barth, Eric J.	Vanderbilt Univ.
Co-Chair: Rastgaar, Mohammad	Michigan Tech.

10:15-10:35	TuAT5.1

Robust Maneuver Based Design of Passive-Assist Devices for Augmenting Robotic Manipulator Joints, pp. 1196-1204

Brown, W. Robert	Univ. of Michigan
Ulsoy, A. Galip	Univ. of Michigan

A methodology for designing a parallel, passive-assist device to augment an active system using energy minimization based on a known maneuver is presented. Implementation of the passive-assist device can result in an improvement in system performance with respect to efficiency, reliability, and/or utility. In previous work we demonstrated this concept experimentally on a single link robot arm augmented with a torsional spring. Here we show that the concept can effectively be applied to more complicated machines performing known periodic motions by simulating a 3-link manipulator arm. The arm can be decoupled prior to optimization using inverse dynamics - greatly simplifying the optimization problem. The addition of optimized springs results in a system-wide decrease in energy consumption of 70.9%. Finally, we consider a distribution of possible maneuvers and use the concepts of robust design to find springs that increase the guaranteed energy savings at a 90% confidence level.

10:35-10:55	TuAT5.2

On the Design and Control of Knee Exoskeleton (I), pp. 1205-1210

Tung, Wayne Yi-Wei	Univ. of California, Berkeley
Kazerooni, Homayoon	Univ. of California at Berkeley
Hyun, Dong Jin	Massachusetts Inst. of Tech.
McKinley, Stephen	UC Berkeley

This paper describes a lightweight (2.7 pounds) exoskeleton orthotics knee which provides controllable resisting torque. In particular, exoskeleton knee uses friction forces between two surfaces to provide resistive torque and impede the knee flexion. Creating an impeding torque at the exoskeleton knee will decrease the torque that needs to be provided by the wearer at his/her knee during flexion. The required external power (from batteries) to provide the controllable resistive torque is minimal in comparison to the dissipated locomotion power since the resistive torque generation is “self-energizing” and is using the energy of the knee itself for braking. The exoskeleton knee uses the absolute angle of the thigh for basic functionality; no other measurements such as ground reaction force or the knee joint angle are necessary for basic performance. This allows the exoskeleton knee to be worn not only independently on the wearer's knee but also in conjunction with hip, ankle or foot exoskeletons. This gives a great deal of flexibility for use of exoskeleton knees in variety of medical, civilian and military applications.

10:55-11:15	TuAT5.3

Optimized Control of Different Actuation Strategies for FES and Orthosis Aided Gait (I), pp. 1211-1220

Kirsch, Nicholas	Univ. of Pittsburgh
Alibeji, Naji A	Univ. of Pittsburgh
Sharma, Nitin	Univ. of Pittsburgh

A combination of functional electrical stimulation (FES) and an orthosis can be used to restore lower limb function in persons with paraplegia. This artificial intervention may allow them to regain the ability to walk again, however, only for short time durations. To improve the time duration of hybrid (FES and orthosis) gait, the muscle fatigue due to FES and the fatigue in arms, caused by a user's supported weight on a walker, needs to be minimized. In this paper, we show that dynamic optimization can be used to compute stimulation/torque profiles and their corresponding joint angle trajectories which minimize electrical stimulation and walker push or pull forces. Importantly, the computation of these optimal stimulation or torque profiles did not require a predefined or a nominal gait trajectory (i.e., a tracking control problem was not solved). Rather the trajectories were computed based only on pre-defined end-points. For optimization we utilized the recently developed three-link dynamic walking model, which includes both single and double support phases and muscle dynamics. Moreover, different optimal actuation strategies for FES and orthosis aided gait under various scenarios (e.g., use of a powered or an unpowered orthosis combined with stimulation of all or few selected lower-limb muscles) were calculated. The qualitative comparison of these results depict the advantages and disadvantages of each actuation strategy. The computed optimal FES/orthosis aided gait were also compared with able-bodied trajectories to illustrate how they differed from able-bodied walking.

11:15-11:35	TuAT5.4

Regulation of 3D Human Arm Impedance through Muscle Co-Contraction, pp. 1221-1229

Patel, Harshil	Arizona State Univ.
O'Neill, Gerald, D	Arizona State Univ.
Artemiadis, Panagiotis	Arizona State Univ.

Humans have the inherent ability of performing highly dexterous and skillful tasks with their arms, involving maintenance of posture, movement, and interaction with the environment. The latter requires the human to control the dynamic characteristics of the upper limb musculoskeletal system. These characteristics are quantitatively represented by inertia, damping, and stiffness, which are measures of mechanical impedance. Many previous studies have shown that arm posture is a dominant factor in determining the end point impedance on a horizontal (transverse) plane. This paper presents the characterization of the end point impedance of the human arm in three-dimensional space. Moreover, it models the regulation of the arm impedance with respect to various levels of muscle co-contraction. The characterization is made by route of experimental trials where human subjects maintained arm posture while their arms were perturbed by a robot arm. Furthermore, the subjects were asked to control the level of their arm muscles' co-contraction, using visual feedback of their muscles' activation, in order to investigate the effect of this muscle co-contraction on the arm impedance. The results of this study show a very interesting, anisotropic increase of arm stiffness due to muscle co-contraction. These results could lead to very useful conclusions about the human's arm biomechanics, as well as many implications for human motor control- specifically the control of arm impedance through muscle co-contraction.

11:35-11:55	TuAT5.5

Ankle Angles During Step Turn and Straight Walk: Implications for the Design of a Steerable Ankle-Foot Prosthetic Robot, pp. 1230-1234

Ficanha, Evandro	Michigan Technological Univ.
Rastgaar, Mohammad	Michigan Tech.
Moridian, Barzin	Michigan Tech. Univ.
Mahmoudian, Nina	Michigan Tech. Univ.

This article compares the three-dimensional angles of the ankle during step turn and straight walking. We used an infrared camera system (Qualisys Oqus ®) to track the trajectories and angles of the foot and leg at different stages of the gait. The range of motion (ROM) of the ankle during stance periods was estimated for both straight step and step turn. The duration of combined phases of heel strike and loading response, mid stance, and terminal stance and pre-swing were determined and used to measure the average angles at each combined phase. The ROM in Inversion/Eversion (IE) increased during turning while Medial/Lateral (ML) rotation decreased and Dorsiflexion/Plantarflexion (DP) changed the least. During the turning step, ankle displacement in DP started with similar angles to straight walk (-9.68° of dorsiflexion) and progressively showed less plantarflexion (1.37° at toe off). In IE, the ankle showed increased inversion leaning the body toward the inside of the turn (angles from 5.90° to 13.61°). ML rotation initiated with an increased medial rotation of 5.68° relative to the straight walk transitioning to 12.06° of increased lateral rotation at the toe off. A novel tendon driven transtibial ankle-foot prosthetic robot with active controls in DP and IE directions was fabricated. It is shown that the robot was capable of mimicking the recorded angles of the human ankle in both straight walk and step turn.

11:55-12:15	TuAT5.6

Design of a Stirling Thermocompressor for a Pneumatically Actuated Ankle-Foot Orthosis, pp. 1235-1243

Kumar, Nithin	Vanderbilt Univ.
Hofacker, Mark	Vanderbilt Univ.
Barth, Eric J.	Vanderbilt Univ.

This paper presents the design, modeling, and simulated performance of a prototype Stirling thermocompressor. The thermocompressor is intended to be mounted on the back of a user's lower leg and convert a hydrocarbon fuel source into 50 W of pneumatic power at 650 kPa to power an ankle foot orthosis. Consisting only of a displacer piston, the Stirling thermocompressor's displacer piston motion is directly controlled by a brushless DC motor so that the frequency of operation can be tuned to output the maximum power. Simulation indicates that this operating frequency is influenced by the intended reservoir pressure and heat transfer properties of the thermocompressor.

TuAT6	Room 134

Control, Monitoring, and Energy Harvesting of Vibratory Systems: Analysis and Passive Control (Invited session)

Chair: Tang, Jiong	Univ. of Connecticut
Co-Chair: Nishimura, Hidekazu	Keio Univ.
Organizer: Zuo, Lei	Stony Brook Univ. - SUNY
Organizer: Tang, Jiong	Univ. of Connecticut
Organizer: Sipahi, Rifat	Northeastern Univ.
Organizer: Caruntu, Dumitru	Univ. of Texas Pan American
Organizer: Nishimura, Hidekazu	Keio Univ.
Organizer: Kajiwara, Itsuro	Hokkaido Univ.

10:15-10:35	TuAT6.1

Study on Novel Tuned Mass Dampers Utilizing Plural Auxiliary Masses to Expand Vibration Suppression Performance under the Conditions of Limited Mass Ratio (I), pp. 1244-1249

Watanabe, Toru	Nihon Univ.
Usuki, Daiki	Graduate Student, School of Science and Tech. Nihon Univ.
Seto, Kazuto	Seto Vibration Control Lab.

This paper proposes two types of novel Tuned Multi-mass Dampers (TMMD), namely Unequally-divided TMMD (UTMMD) and Wired TMMD (WTMMD). It is widely known that the vibration suppression effect of ordinary TMD is dominated by the mass ratio, namely the ratio of the weight of the auxiliary mass to the weight of control object. Besides, it is already known that the TMMD made of plural identical tuned mass dampers (TMDs) achieves higher vibration suppression effect than a single big TMD even if the total weights of auxiliary masses of TMMD is equal with that of TMD. In this study, the idea of UTMMD made of plural unequal TMDs is presented and its vibration suppression effect is explored numerically. It is clarified that the vibration suppression effect of UTMMD is essentially the same as that of TMD, while the robustness of UTMMD might be better than that of TMD. Meanwhile, the stroke of ordinary TMD is generally restricted due to the mechanical limitation such as the elastic range of spring. The limited stroke obstructs the applicability of TMD against the control object subjected to larger excitation force or longer excitation amplitude. Therefore the extension of the stroke of TMD is an important issue. WTMMD is another novel TMMD made of an auxiliary mass connected with two small auxiliary masses via wires for each. The tensions of the wires due to their elasticity and the weights of small auxiliary masses give the main auxiliary mass restoring force, while the wires allow the main auxiliary mass to move over longer stroke than ordinary springs allow. In this study, an experimental structure and WTMMD is built, and vibration suppression property of WTMMD is investigated experimentally. The WTMMD showed satisfactory vibration suppression performance.

10:35-10:55	TuAT6.2

Reduced Order Model of Parametric Resonance of Electrostatically Actuated CNT Cantilever Resonators (I), pp. 1250-1254

Caruntu, Dumitru	Univ. of Texas Pan American
Luo, Le	Univ. of Texas Pan American

This paper deals with electrostatically actuated Carbon Nano-Tubes (CNT) cantilevers using Reduced Order Model (ROM) method. Forces acting on the CNT cantilever are electrostatic, van der Waals, and damping. The van der Waals forces are significant for values of 50 nm or lower of the gap between the CNT and the ground plate. As both forces electrostatic and van der Waals are nonlinear, and the CNT electrostatic actuation is given by AC voltage, the CNT undergoes nonlinear parametric dynamics. The Method of Multiple Scales (MMS), and ROM are used to investigate the system under soft excitations and/or weak nonlinearities. The frequency-amplitude and frequency-phase behaviors are found in the case of parametric resonance.

10:55-11:15	TuAT6.3

Analysis of a Bi-Harmonic Tapping Mode for Atomic Force Microscopy (I), pp. 1255-1262

Loganathan, Muthukumaran	Missouri Univ. of Science and Tech.
Bristow, Douglas A.	Missouri Univ. of Science and Tech.

The tapping mode (TM) is a popularly used imaging mode in atomic force microscopy (AFM). A feedback loop regulates the amplitude of the tapping cantilever by adjusting the offset between the probe and sample; the image is generated from the control action. This paper explores the role of the trajectory of the tapping cantilever in the accuracy of the acquired image. This paper demonstrates that reshaping the cantilever trajectory alters the amplitude response to changes in surface topography, effectively altering the mechanical sensitivity of the instrument. Trajectory dynamics are analyzed to determine the effect on mechanical sensitivity and analysis of the feedback loop is used to determine the effect on image accuracy. Experimental results validate the analysis, demonstrating better than 30% improvement in mechanical sensitivity using certain trajectories. Images obtained using these trajectories exhibit improved sharpness and surface tracking, especially at high scan speeds.

11:15-11:35	TuAT6.4

Perturbing Structural Design towards Minimizing Variation in Vibratory Response (I), pp. 1263-1267

Zhou, Kai — Univ. of Connecticut
Tang, Jiong — Univ. of Connecticut

Real structures are always subject to uncertainties due to material imperfection, machining tolerance, and assemblage error, etc. These uncertainties lead to variations in structural vibratory responses. In order to reduce the likelihood of unexpected failures in structures, we need to minimize the response variations, which is the underlying idea of robust design. In this paper, we present an inverse sensitivity-based algorithm that allows us to tailor the structural design such that, under the same level of uncertainties, the response variations can be effectively reduced. We first develop a direct relation between the structural uncertainties and the response variations including the means and variances. We then formulate an optimal identification algorithm that will yield design perturbation to minimize the response variances while maintaining the mean values. Case analyses are carried out to validate the validity and efficiency of the new algorithm.

11:35-11:55 — TuAT6.5

Detection of Contact-Type Damages by Utilizing Nonlinear Piezoelectric Impedance Modulation of Self-Excited Structures (I), pp. 1268-1274

Masuda, Arata — Kyoto Inst. of Tech.
Ogawa, Yuya — Kyoto Inst. of Tech.
Sone, Akira — Kyoto Inst. of Tech.

This paper presents an improvement of a nonlinear piezoelectric impedance modulation (NPIM)-based damage detection method, a damage-sensitive, baseline-free structural health monitoring technique proposed by the authors, by introducing self-excited oscillation. The NPIM-based damage detection utilizes the modulation of high-frequency wave field of structures caused by the contact acoustic nonlinearity at the damaged part. In this study, the high-frequency wave field is induced as a self-excited oscillation of the structure by positively feed-backing the strain signal measured by a surface-bonded piezoelectric sensor, followed by a phase-shift in 90 degrees and a nonlinear element consisting of a saturation element and a negative linear gain. The induced self-excitation can have multiple stable limit cycles at certain eigenmode frequencies, and one can switch among them by inputting an auxiliary excitation signal into the feedback loop. The current flowing through the piezoelectric sensor is measured to detect its modulation due to the stiffness fluctuation due to the existence of the contact-type damage. Experiments using a specimen with a simulated damage are conducted to examine the performance of the self-excitation circuit and its applicability to the NPIM-based damage detection method.

11:55-12:15 — TuAT6.6

Study on the Vibration Response of Axially Moving Continua (I), pp. 1275-1284

Chung, Chunhui — National Taiwan Univ. of Science and Tech.
Kao, Imin — Stony Brook Univ.

Axially moving continua such as belt, chain, and conveyer are common transmission components. The study of the vibration response of axially moving continua is an essential topic to understand the fundamentals of vibration and improve the performance of the machines. However, it typically requires more rigorous effort in mathematical derivation to obtain the analytical forced vibration responses of the axially moving continua because of the characteristics of non-self-adjoint equation of motion. The methods utilized to obtain the analytical solutions include the modal analysis, canonical form, wave propagation, Laplace transform, and transfer function. In this review paper, these methods will be reviewed and presented. The advantages and disadvantages of different methodologies are discussed as well.

TuAT7 — Room 138

Optimization and Optimal Control (Contributed session)

Chair: Tulpule, Punit — Iowa State Univ.
Co-Chair: Li, Yaoyu — Univ. of Texas at Dallas

10:15-10:35 — TuAT7.1

Discrimination of Steady State and Transient State of Extremum Seeking Control Via Sinusoidal Detection, pp. 1285-1294

Mu, Baojie — The Univ. of Texas at Dallas
Li, Yaoyu — Univ. of Texas at Dallas
Seem, John E. — Johnson Controls Inc.

A major class of extremum seeking control is based on the use of periodic dither perturbation of plant input for extracting the gradient information. Presence of the dither input into the steady state operation is undesirable in practice due to the possible excessive wear of actuators. It is thus beneficial to stop the dithering action after the extremum seeking process reaches its steady state. In this paper, we propose a method for automatically discriminate between the steady state and the transient state modes of extremum seeking control process using the sinusoidal detection techniques. Some design guidelines are proposed for the parameter selection of the relevant sinusoidal detection scheme. The proposed scheme is validated with simulation study.

10:35-10:55 — TuAT7.2

Governing Parameter Changes in Nonlinear Parameter-Dependent Optimization Problems, pp. 1295-1304

Gupta, Rohit — Univ. of Michigan
Kolmanovsky, Ilya — The Univ. of Michigan, Ann Arbor

The paper treats a class of parameter-dependent optimization/root finding problems where the minimizer or a real root need to be determined as a function of parameter. Applications of parameter-dependent optimization include spacecraft debris avoidance, adaptive control of Hybrid Electric Vehicles, engine mapping and model predictive control. In these and other problems, the parameter changes can be controlled either directly or indirectly. The error analysis of a dynamic predictor-corrector Newton's type algorithm is presented. Based on this analysis, an approach to govern the changes in the parameter to enable the algorithm to track the minimizer within an acceptable error bound is described. Two simulation examples are presented. In the first example the objective is to minimize the distance between points on a curve and a given set and simultaneously move as fast as possible along the given curve. In the second example the objective is to illustrate the use of this technique for flight envelope estimation. Specifically, we estimate maximum speed of an aircraft as a function of its altitude.

10:55-11:15 — TuAT7.3

Optimal Compression of a Generalized Prandtl-Ishlinskii Operator in Hysteresis Modeling, pp. 1305-1314

Zhang, Jun — Michigan State Univ.
Merced, Emmanuelle — Michigan State Univ.
Sepulveda, Nelson — Michigan State Univ.
Tan, Xiaobo — Michigan State Univ.

The Prandtl-Ishlinskii (PI) model is a popular hysteresis model that has been widely applied in smart materials-based systems. Recently, a generalized PI model is formulated that is capable of characterizing asymmetric, saturated hysteresis. The fidelity of the model hinges on accurate representation of envelope functions, play operator radii, and corresponding weights. For a given number of play operators, existing work has typically adopted some predefined play radii, the performance of which could be far from optimal. In this paper, novel schemes based on entropy and relative entropy (Kullback-Leibler divergence) for optimal compression of a generalized PI model are proposed to best represent the original hysteresis model subject to a given complexity constraint, i.e., the number of play operators. The overall compression performance is expressed as a cost function, and is optimized using dynamic programming. The proposed compression schemes are applied to the modeling of the asymmetric hysteresis between resistance and temperature of a vanadium dioxide (VO2) film, and the effectiveness is further demonstrated in a model verification experiment. In particular, under the same complexity constraint, an entropy-based compression scheme and a Kullback-Leibler divergence-based compression scheme result in modeling errors around 37 % and 48 %, respectively, of that under a uniform compression scheme.

11:15-11:35	TuAT7.4

A Gradient-Based Method for Team Evasion, pp. 1315-1323

Liu, Shih-Yuan	Univ. of California, Berkeley
Zhou, Zhengyuan	Univ. of California, Berkeley
Tomlin, Claire J.	UC Berkeley
Hedrick, Karl	Univ. of California at Berkeley

We formulate an autonomous agent team facing the attack of an adversarial agent as a single-pursuer-multiple-evader pursuit-evasion game, with the assumption that the pursuer is faster than all evaders. In this game, the pursuer aims to minimize the capture time of the last surviving evader, while the evaders as a team cooperate to maximize this time. We present a gradient-based approach that quickly computes the controls for the evaders as a team under an open-loop formulation that is conservative towards the evader team by deriving analytical formulas. We demonstrate the advantage of the gradient-based approach by comparing performance both in computation time and in optimality with the iterative open-loop method studied in our previous work. Multiple heuristics have been designed to deal with the inherent intractability of evaluating all possible capture sequences. Extensive simulation have been performed, with results discussed.

11:35-11:55	TuAT7.5

Bmi Based Robust Optimal Control Synthesis Via Sensitivity Minimization, pp. 1324-1332

Tulpule, Punit	Iowa State Univ.
Kelkar, Atul	Iowa State Univ.

This paper revisits the sensitivity minimization approach with new formulation and synthesis methodology. The new robust control synthesis approach is presented here with a numerical example of an application to a header height control of combine harvester machine. The proposed synthesis methodology is compared with the H-infinity control design by comparing the performance of controllers designed using both techniques. The results indicate that the proposed methodology provides a viable alternative for robust controller synthesis and can even be better in robust performance in many cases.

11:55-12:15	TuAT7.6

Research on an Approximate Model Based Virtual Calibration Method with Doe and Optimization Algorithm for Transmission Control Unit, pp. 1333-1338

Wu, Guangqiang	Tongji Univ.
Sun, Lu	Tongji Univ.
Zhu, Sheng	Tongji Univ.
Zhang, Kuankuan	Tongji Univ.

In order to solve the problems arising from the manual calibration method in the developing process of vehicle automatic transmission control unit (TCU), known as time-consuming, heavy workload, high cost and over-dependence on subjective experience, this article researches on a virtual calibration method based on an approximate model to obtain optimal parameters for TCU. The neural network approximate model is established from the test data chosen with the method of DoE (Design of Experiment). The virtual calibration method is then conducted through Optimal Latin Hypercube Design (OLHD) and multi-island genetic algorithm (MIGA) to search the optimal parameters. By comparing the new calibration method with original manual one on the condition of gear 1 up to gear 2, the result shows that the new method can increase the efficiency significantly.

TuBT1	Paul Brest East
Automotive Control Systems (Contributed session)	
Chair: Canova, Marcello	The Ohio State Univ.
Co-Chair: Shahbakhti, Mahdi	Michigan Tech. Univ.

13:30-13:50	TuBT1.1

Multi-Input Observer for Estimation of Compressor Flow, pp. 1339-1343

Kalabic, Uros	Univ. of Michigan
Kolmanovsky, Ilya	The Univ. of Michigan, Ann Arbor
Buckland, Julia	Ford Motor Company

This paper presents a formulation and an application of a high-gain multi-input observer to estimate the compressor flow in turbocharged gasoline engines. Such an observer is desired in vehicles lacking a mass air flow sensor yet in which compressor flow needs to be known; for instance, it is desired in order to apply a reference governor for surge constraint avoidance. In this application, a fast estimate of the compressor flow is required so that the reference governor can take action before the compressor goes into surge. The multi-input observer uses pressure measurements and cylinder flow to estimate the compressor flow. This paper presents the derivation of the observer and both simulation and experimental results showing its feasibility in estimating the compressor flow.

13:50-14:10	TuBT1.2

Rate-Based Contractive Model Predictive Control of Diesel Air Path, pp. 1344-1348

Huang, Mike	Univ. of Michigan
Butts, Kenneth	Toyota Motor Engineering and Manufacturing, NA
Polavarapu, Srinivas	Belcan Corp.
Kolmanovsky, Ilya	The Univ. of Michigan, Ann Arbor
Nakada, Hayato	Toyota Motor Corp.

A model predictive control (MPC) strategy is developed for the diesel engine air path. The objective is to regulate the intake manifold pressure (MAP) and exhaust gas recirculation rate (EGR rate) to the specified set-points by coordinated control of the Variable Geometry Turbine (VGT), and EGR valve. The approach taken enforces a decay in a flexible Lyapunov function so that a computationally simple MPC can be constructed using a single-step prediction and control horizon. A rate-based framework is also utilized to achieve zero-steady state tracking in the presence of model and plant mismatch. Closed-loop simulation results are reported.

14:10-14:30	TuBT1.3

On-Line Fault Detection and Isolation (FDI) for the Exhaust Path of a Turbocharged SI Engine (I), pp. 1349-1358

Salehi, Rasoul	Sharif Univ. of Tech.
Shahbakhti, Mahdi	Michigan Tech. Univ.
Alasty, Aria	Sharif Univ. of Tech.
Vossoughi, Gholamreza	Sharif Univ. of Tech.

Detection and isolation of faults in the exhaust gas path of a turbocharged spark ignition (SI) engine is an essential part of the engine control unit (ECU) strategies to minimize exhaust emission and ensure safe operation of a turbocharger. This paper proposes a novel physics-based strategy to detect and isolate an exhaust manifold leakage and a closed-stuck wastegate fault. The strategy is based on a globally optimal parameter estimation algorithm which detects an effective hole area in the exhaust manifold. The estimation algorithm requires prediction of the exhaust manifold's input and output flows. The input flow is predicted by a nonlinear Luenberger observer which is analytically shown to be robust to the faults in the exhaust manifold. The output flow of the exhaust manifold is detected by a sliding mode observer. The designed fault diagnosis and isolation (FDI) strategy is tested with the experimental data collected

from a 1.7-liter turbocharged SI engine. The validation results show that the FDI strategy can detect a leakage fault from a 5mm hole in the exhaust manifold, and can identify the wastegate stuck faults.

14:30-14:50	TuBT1.4

Lumped-Parameter Modeling of an Automotive Air Conditioning System for Energy Optimization and Management, pp. 1359-1366

Zhang, Quansheng — the Ohio State Univ.
Canova, Marcello — The Ohio State Univ.

The air conditioning (A/C) system is the largest ancillary load in passenger cars, with significant impact on fuel economy. In order to reduce the energy consumption of A/C systems, model-based optimization and optimal control design tools can be effectively applied to design of a supervisory energy management strategy. Significant challenges however lie in the design of a system model that is accurate enough to represent the nonlinear behavior of the system, yet sufficiently simple to enable the use of model-based control design methods. This paper presents a low-order, energy-based model of an automotive A/C system that is able to predict the dynamics of the evaporator and condenser pressures and the compressor power consumption during typical thermostatic (on/off) operations. A characterization of the mass and energy transport in the heat exchangers is obtained using a lumped-parameter approximation, leading to a model with reasonable accuracy but greatly reduced complexity, hence for supervisory control design. The model was validated against experimental data obtained on a test vehicle, allowing one to evaluate the accuracy in predicting the pressure states and the power consumption.

14:50-15:10	TuBT1.5

Conceptual Design and Simulation of the Traction Control System of a High Performance Electric Vehicle (I), pp. 1367-1375

Nuñez, Juan Sebastian — Univ. de los Andes
Muñoz, Luis Ernesto — Univ. de los Andes

This paper presents the conceptual design of the traction control system of a high performance electric vehicle with four driven wheels, intended to be used in quarter mile competitions. Different models of the longitudinal and vertical vehicle's dynamics are presented, in order to consider the coupling dynamics of front and rear wheels. Two slip control strategies are proposed so as to maximize the traction forces of the wheels. The first one consists of a traditional control scheme applied to each wheel of the vehicle. Since the interaction between the tire and the road is often poorly known, the second controller proposed consists of a perturbation based extremum seeking control (PBESC), in order to maximize the traction force without knowledge of the road and the tire characteristics. Finally an auto tuning process based on low discrepancy sequences for both control systems is presented.

15:10-15:30	TuBT1.6

Nonlinear Clutch Engagement Control, pp. 1376-1380

Chen, Jyh-Shin — General Motors
Zhu, Yongjie — GM

Clutches are used to connect and disconnect shafts in mechanical systems. They are extensively used in transmissions for hybrid electric and conventional vehicles. Smooth clutch engagement is needed for good drivability. Poor clutch engagement will excite driveline vibration and cause driver discomfort.

Smooth clutch engagement is not a trivial task. For a slipping clutch, the torque transmitted through a clutch is dictated by the torque capacity, which is a function of clutch dimensions, friction coefficients and normal force. When a clutch is locked, the transmitted torque is not dictated by the torque capacity anymore. Instead, the transmitted torque is equal to the torque required to lock the clutch. Therefore, a discontinuity in transmitted torque will occur if a clutch is not engaged properly. The discontinuity will cause a driveline to oscillate.

When a PID control is used to control clutch engagement, a nonzero integral term is usually required to guarantee lockup. This integral term often causes trouble when the PID gains are not carefully tuned. Gain tuning is time consuming and sometimes difficult to get good results. A reference slip profile is often needed in a PID approach. It adds additional complexity to the design process.

This paper introduces a nonlinear control to engage a clutch smoothly. The control does not use the clutch torque capacity to control clutch slip. Instead, it regulates the torque applied to the inertia at the clutch input. The control requires very little calibration. Simulation results are presented. Theoretical proofs for stability and robustness are also included.

TuBT2	Room 123
Haptics and Hand Motion (Contributed session)	
Chair: O'Malley, Marcia	Rice Univ.
Co-Chair: Okamura, Allison	Stanford Univ.

13:30-13:50	TuBT2.1

User-Independent Hand Motion Classification with Electromyography, pp. 1381-1386

Gibson, Alison — Arizona State Univ.
Ison, Mark — Arizona State Univ.
Artemiadis, Panagiotis — Arizona State Univ.

Electromyographic (EMG) processing is an important research area with direct applications to prosthetics, exoskeletons and human-machine interaction. Current state of the art decoding methods require intensive training on a single user before it can be utilized, and have been unable to achieve both user-independence and real-time performance. This paper presents a real-time EMG classification method which generalizes across users without requiring an additional training phase. An EMG-embedded sleeve quickly positions and records from EMG surface electrodes on six forearm muscles. An optimized decision tree classifies signals from these sensors into five distinct movements for any given user using EMG energy synergies between muscles. This method was tested on 10 healthy subjects using leave-one-out validation, resulting in an overall accuracy of 79%, with sensitivity and specificity averaging 66% and 97.6%, respectively, over all classified motions. The high specificity values demonstrate the ability to generalize across users, presenting opportunities for large-scale studies and broader accessibility to EMG-driven applications.

13:50-14:10	TuBT2.2

A Method for Selecting Velocity Filter Cutoff Frequency for Maximizing Impedance Width Performance in Haptic Interfaces, pp. 1387-1394

Chawda, Vinay — Rice Univ.
Celik, Ozkan — San Francisco State Univ.
O'Malley, Marcia — Rice Univ.

This paper analyzes the effect of velocity filtering cut-off frequency on the Z-width performance in haptic interfaces. Finite Difference Method (FDM) cascaded with a lowpass filter is the most commonly used technique for estimating velocity from position data in haptic interfaces. So far, there is no prescribed method for obtaining the FDM+filter cut-off frequency that will maximize the Z-width performance. We present a simulation based method to demonstrate that there exists such an ideal FDM+filter cut-off frequency, and that it can be predicted by numerical simulation. Experiments are conducted on a single degree-of-freedom linear haptic interface to validate the simulation results.

14:10-14:30	TuBT2.3

Haptic Glove Using Compression-Induced Friction Torque, pp. 1395-1401

Kuroda, Yoshihiro — Osaka Univ.
Shigeta, Yu — Osaka Univ.
Imura, Masataka — Osaka Univ.

Uranishi, Yuki — Osaka Univ.
Oshiro, Osamu — Osaka Univ.

The aim of this study is to develop a compact haptic glove that can present a variety of grasping sensations. This paper proposes a mechanism of compressing a finger joint to induce friction torque between the link and joint. In order to reduce weight and produce greater force, shape memory alloys were chosen as an actuator. The result of an experiment showed a linear relationship between the compressing force of a finger joint and friction torque, and suggested the effectiveness of the proposed mechanism. The prototype system suggested the proposed device is small and lightweight compared to the conventional device.

14:30-14:50 — TuBT2.4

Evaluation of Friction Models for Haptic Devices, pp. 1402-1410

Ahmad, Aftab — KTH, Royal Inst. of Tech.
Andersson, Kjell — KTH, Royal Inst. of Tech.
Sellgren, Ulf — KTH Royal Inst. of Tech.
Boegli, Max — KU Leuven

In this work different friction models are evaluated to determine how well these models are suited for performance simulation and control of a 6-DOF haptic device. The studied models includes, Dahl model, LuGre model, Generalized Maxwell slip model (GMS), smooth Generalized Maxwell slip model (S-GMS) and Differential Algebraic Multistate (DAM) friction model. These models are evaluated both numerically and experimentally with an existing 6-DOF haptic device that is based on a Stewart platform. In order to evaluate how well these models compensate friction, a model-based feedback friction compensation strategy along with a PID controller were used for position tracking accuracy. The accuracies of the friction compensation models are examined separately for both low-velocity and high-velocity motions of the system. To evaluate these models, we use criteria based on fidelity to predict realistic friction phenomena, easiness to implement, computational efficiency and easiness to estimate the model parameters. Experimental results show that friction compensated with GMS, S-GMS and DAM models give better accuracy in terms of standard deviation, mean and maximum error between a reference and measured trajectory. Based on the criteria of fidelity, ease of implementation and ease to estimate model parameters, the S-GMS model, which represents a smooth transition between sliding and pre-sliding regime through an analytical set of differential equations, is suggested.

14:50-15:10 — TuBT2.5

Model-Mediated Teleoperation with Predictive Models and Relative Tracking, pp. 1411-1415

Winck, Ryder C. — Stanford Univ.
Okamura, Allison — Stanford Univ.

This paper presents a model-mediated approach for teleoperation with haptic feedback in the presence of time delays on the order of seconds. The target application for the control scheme is teleoperation of robotic manipulators for space systems in geosynchronous orbit. Previous work in model-mediated teleoperation allowed operators to interact with a virtual model of the remote robot and environment, where the remote robot follows the operator's commands after a delay and the virtual model is updated when the remote data is available. Our approach adds predictive models, mediated command execution, and a dynamic slave model. A single-degree-of-freedom experiment using a simulated robot and environment demonstrate improvements in the control of remote robot position and environment contact forces, in comparison to previous approaches.

15:10-15:30 — TuBT2.6

A Haptic System for Educational Games: Design and Application-Specific Kinematic Optimization, pp. 1416-1420

Kessler, Jeffrey A. — Stanford Univ.
Lovelace, R. Curtis — Stanford Univ.
Okamura, Allison — Stanford Univ.

HAPTIC PONG is a force-feedback version of the classic arcade game "Pong", conceived as an educational game that can teach physics and controls concepts to high school students. Our design incorporates two identical linear one-degree-of-freedom haptic paddles, each with a four-bar linkage transforming motor rotation to linear motion. Virtual environments were designed to incorporate dynamic systems describing the force-displacement relationships of each paddle. At a demonstration with 50 high school students, a prototype of the device was rated as both educational and fun to use. After the initial proof of concept, a design optimization study was conducted to improve the kinematic performance of the linear haptic devices based on the device constraints for the application. Optimization considered both the linearity of the coupler point and Jacobian minimum singular value. While maintaining a satisfactory level of linearity, the optimized linkage lengths produced an estimated 160% improvement in the maximum consistent force output.

TuBT3 — Tent A

Vehicles and Human Robotics (Contributed session)

Chair: Fathy, Hosam K. — The Pennsylvania State Univ.
Co-Chair: Singhose, William — Georgia Inst. of Tech.

13:30-13:50 — TuBT3.1

An Interactive Multimedia Framework for Education on Vehicle Electrification, pp. 1421-1430

Rothenberger, Michael — The Pennsylvania State Univ.
Fathy, Hosam K. — The Pennsylvania State Univ.

This paper presents an interactive multimedia framework for introducing students to vehicle electrification/hybridization. The framework familiarizes its target audience with: (i) the societal factors driving the development of hybrid and plug-in hybrid electric vehicles (HEVs/PHEVs); (ii) the differences between conventional vehicles, HEVs, and PHEVs; and (iii) the high-level performance constraints and tradeoffs inherent in hybrid vehicle design. The framework consists of two coupled components: (i) a set of educational videos on vehicle electrification; and (ii) a 3D videogame built around physics-based models of conventional and series hybrid ambulances. The paper presents both the above education framework and the specific principles from the pedagogy literature guiding its design.

13:50-14:10 — TuBT3.2

A System-Dynamics-Based Hazard Analysis of Inverted-Pendulum Human Transporters, pp. 1431-1440

Adams, Christopher — Georgia Inst. of Tech.
Singhose, William — Georgia Inst. of Tech.
Kim, Dooroo — Georgia Inst. of Tech.

Best practices in product design require engineers to perform preliminary hazard analyses on the most promising conceptual designs, as well as a more rigorous hazard analysis when the details of the product are being finalized. When the product is a complex dynamic system that interacts directly with a human, the engineers must consider the wide range of possible motions and forces that the device could create. Such an analysis goes beyond a simple thought exercise and requires detailed knowledge about the system dynamics and operating environment. This paper presents such an analysis of an inverted-pendulum human transporter. The list of hazards is constructed by using fundamental knowledge of the dynamics and the mechanical design obtained through simulation and experimentation. However, the dynamics are so complex that the list is augmented with hazards that are revealed by searching through accident videos posted on the Internet. The severity of each hazard is estimated using an energy-based measurement of the hazard onset conditions. While this case study is interesting, it also provides a systematic approach to hazard analysis that can be applied to other complex and dangerous dynamic systems.

14:10-14:30	TuBT3.3

Navigation of an Underwater Remotely Operated Vehicle Based on Extended Kalman Filter (I), pp. 1441-1449

Martinez Carvajal, Blanca Viviana	Univ. Industrial de Santander
Sierra Bueno, Daniel Alfonso	Univ. Industrial de Santander
Villamizar Mejia, Rodolfo	Univ. Industrial de Santander

An algorithm to estimate positions, orientations, linear velocities and angular rates of an Underwater Remotely Operated Vehicle (UROV), based on the Extended Kalman Filter (EKF), is presented. The complete UROV kinematic and dynamic models are combined to obtain the process equation, and measurements correspond to linear accelerations and angular rates provided by an Inertial Measurement Unit (IMU). The proposed algorithm is numerically validated and its results are compared with simulated UROV states. A discussion about the influence of the covariance matrices on the estimation error and overall filter performance is also included. As a conclusion, the proposed algorithm estimates properly the UROV linear velocities and angular rates from IMU measurements, and the noise in estimated states is reduced in about one order of magnitude.

14:30-14:50	TuBT3.4

Simulation of the Dynamic Behavior of Ships Based on Slender-Body Theory (sbt) (I), pp. 1450-1459

Tascon Muñoz, Oscar Dario	COTECMAR
Mora Paz, Jaime David	COTECMAR
Algarin Roncallo, Roberto	COTECMAR

One of the aims of the Colombian Ministry of Defense in the field of science and technology is to develop and build in-house simulators for training. Aligned with this objective, the Science & Technology Corporation for the Development of the Shipbuilding Industry in Colombia – COTECMAR has established a research program in the development of physics-based models to predict the generalized forces acting on maneuvering ships. Thus, a mathematical model for the prediction of the dynamic behavior of ships has been formulated. In order to get an analytical method and to minimize computational time, the hydrodynamic forces for this model are derived from slender-body theory (SBT) and finally a generalized formulation is achieved. In the present work, the description of the modular form of the model together with comparisons between the present results and reference data are presented for the case of displacement ships, submarines and planing hulls.

14:50-15:10	TuBT3.5

Bio-Inspired Robot Control for Human-Robot Bi-Manual Manipulation, pp. 1460-1467

Warren, Stephen	Arizona State Univ.
Artemiadis, Panagiotis	Arizona State Univ.

As robots are increasingly used in human-cluttered environments, the requirement of human-likeness in their movements becomes essential. Although robots perform a wide variety of demanding tasks around the world in factories, remote sites and dangerous environments, they are still lacking the ability to coordinate with humans in simple, every-day life bi-manual tasks, e.g. removing a jar lid. This paper focuses on the introduction of bio-inspired control schemes for robot arms that coordinate with human arms in bi-manual manipulation tasks. Using data captured from human subjects performing a variety of every-day bi-manual life tasks, we propose a bio-inspired controller for a robot arm, that is able to learn human inter- and intra-arm coordination during those tasks. We embed human arm coordination in low-dimension manifolds, and build potential fields that attract the robot to human-like configurations using the probability distributions of the recorded human data. The method is tested using a simulated robot arm that is identical in structure to the human arm. A preliminary evaluation of the approach is also carried out using an anthropomorphic robot arm in bi-manual manipulation task with a human subject.

15:10-15:30	TuBT3.6

Modeling and Simulation of Human Walking with Wearable Powered Assisting Device (I), pp. 1468-1473

Slavnić, Siniša	Univ. of Bremen
Leu, Adrian	Univ. of Bremen
Ristić-Durrant, Danijela	Univ. of Bremen
Gräser, Axel	Univ. of Bremen, Inst. of Automation (IAT)

For the purpose of developing robot-assisted human walking systems, human and robot walking dynamics are modeled using models of different complexity depending on simulation scenarios in different phases of robotic system development and selected walking parameters to be analyzed. This paper addresses the early modeling and simulation phase of the development of a novel mobile robot-assisted gait rehabilitation system to be used as a demonstrator for a cognitive robot control architecture currently under development. For simulation purposes dynamical models of walking human and powered orthosis are developed in multi-body simulation software (MSC Adams) using the LifeMod plug-in while the control algorithms are developed in Matlab. The paper introduces a novel ROS (Robot Operating System) based communication established between the real system software modules and the simulation environment. The performance evaluation was performed by running the simulation with motion data which were obtained using marker-based motion capture system and which were implemented as ROS node.

TuBT4	Paul Brest West
Battery Systems (Contributed session)	
Chair: Peng, Huei	Univ. of Michigan
Co-Chair: Fathy, Hosam K.	The Pennsylvania State Univ.

13:30-13:50	TuBT4.1

Approximations for Partial Differential Equations Appearing in Li-Ion Battery Models, pp. 1474-1483

Chaturvedi, Nalin A.	Robert Bosch LLC
Christensen, Jake	Robert Bosch LLC
Klein, Reinhardt	Robert Bosch LLC
Kojic, Aleksandar	Robert Bosch Res. and Tech. Center North America

Li-ion based batteries are believed to be the most promising battery system for HEV/PHEV/EV applications due to their high energy density, lack of hysteresis and low self-discharge currents. However, designing a battery, along with its Battery Management System (BMS), that can guarantee safe and reliable operation, is a challenge since aging and other mechanisms involving optimal charge and discharge of the battery are not sufficiently well understood. In a previous article [1], we presented a model that has been studied in [2]–[5] to understand the operation of a Li-ion battery. In this article, we continue our work and present an approximation technique that can be applied to a generic Li-ion battery model. These approximation method is based on projecting solutions to a Hilbert subspace formed by taking the span of an countably infinite set of basis functions. In this article, we apply this method to the key diffusion equation in the battery model, thus providing a fast approximation for the single particle model (SPM) for both variable and constant diffusion case.

13:50-14:10	TuBT4.2

Battery State of Health and Charge Estimation Using Polynomial Chaos Theory, pp. 1484-1493

Bashash, Saeid	Pennsylvania State Univ.
Fathy, Hosam K.	The Pennsylvania State Univ.

In this effort, we use the generalized Polynomial Chaos theory (gPC) for the real-time state and parameter estimation of electrochemical batteries. We use an equivalent circuit battery model, comprising two states and five parameters, and formulate the online parameter estimation problem using battery current and voltage measurements. Using a combination of the conventional recursive gradient-based search algorithm and gPC framework, we propose a novel battery parameter estimation strategy capable of estimating both battery state-of-charge (SOC) and parameters related to battery health, e.g., battery charge capacity, internal resistance, and relaxation time constant. Using a combination of experimental tests and numerical simulations, we examine and demonstrate the effectiveness of the proposed battery estimation method.

14:10-14:30	TuBT4.3

An Open-Circuit-Voltage Model of Lithium-Ion Batteries for Effective Incremental Capacity Analysis, pp. 1494-1501

Weng, Caihao	Univ. of Michigan
Sun, Jing	Univ. of Michigan
Peng, Huei	Univ. of Michigan

Open-Circuit-Voltage (OCV) is an essential part of battery models for state-of-charge (SOC) estimation. In this paper, we propose a new parametric OCV model, which considers the staging phenomenon during the lithium intercalation/deintercalation process. Results show that the new parametric model improves SOC estimation accuracy compared to other existing OCV models. Moreover, the model is shown to be suitable and effective for battery state-of-health monitoring. In particular, the new OCV model can be used for incremental capacity analysis (ICA), which reveals important information on the cell behavior associated with its electrochemical properties and aging status.

14:30-14:50	TuBT4.4

Hybrid Electric Vehicle Energy Management with Battery Thermal Considerations Using Multi-Rate Dynamic Programming, pp. 1502-1511

Johri, Rajit	Ford Motor Company
Liang, Wei	Ford Motor Company
McGee, Ryan	Ford Motor Company

Battery capacity and battery thermal management control have a significant impact on the Hybrid Electric Vehicle (HEV) fuel economy. Additionally, battery temperature has a key influ- ence on the battery health in an HEV. In the past, battery tem- perature and cooling capacity has not been included while per- forming optimization studies for power management or optimal battery sizing. This paper presents an application of Dynamic Programming (DP) to HEV optimization with battery thermal constraints. The optimization problem is formulated with 3 state variables, namely, the battery State Of Charge (SOC), the en- gine speed and the battery bulk temperature. This optimization is critical for determining appropriate battery size and battery thermal management design. The proposed problem has a major challenge in computation time due to the large state space. The paper describes a novel multi-rate DP algorithm to reduce the computational challenges associated with the particular class of large-scale problem where states evolve at very different rates. In HEV applications, the battery thermal dynamics is orders of magnitude slower than powertrain dynamics. The proposed DP algorithm provides a novel way of tackling this problem with multiple time rates for DP with each time rate associated with the fast and slow states separately. Additionally, the paper gives possible numerical techniques to reduce the DP computational time and the time reduction for each technique is shown.

14:50-15:10	TuBT4.5

Cost-Effective Energy Management for Hybrid Electric Heavy-Duty Truck Including Battery Aging, pp. 1512-1519

Pham, T.H.	Eindhoven Univ. of Tech.
Kessels, J.T.B.A.	Eindhoven Univ. of Tech.
van den Bosch, P.P.J.	Eindhoven Univ. of Tech.
Huisman, R.G.M.	DAF Trucks N.V.

Battery temperature has large impact on battery power capability and battery life time. In Hybrid Electric Heavy-duty trucks (HEVs), the high-voltage battery is normally equipped with an active Battery Thermal Management System (BTMS) guaranteeing a desired battery life time. Since the BTMS can consume a substantial amount of energy, this paper aims at integrating the Energy Management Strategy (EMS) and BTMS to minimize the overall operational cost of the truck (considering diesel fuel cost and battery life time cost). The proposed on-line strategy makes use of the Equivalent Consumption Minimization Strategy (ECMS) along with a physics-based approach to optimize both the power split (between the Internal Combustion Engine (ICE) and the Motor Generator (MG)) and the BTMS's operation. The strategy also utilizes a quasi-static battery cycle-life model taking into account the effects of battery power and battery temperature on the battery capacity loss. Simulation results present an appropriate strategy for EMS and BTMS integration, and demonstrate the trade-off between the total vehicle fuel consumption and the battery life time.

15:10-15:30	TuBT4.6

Comprehensive Battery Equivalent Circuit Based Model for Battery Management Application, pp. 1520-1529

Tong, Shijie	Univ. of California, Davis
Klein, Matthew	Univ. of California, Davis
Park, Jae Wan	UC Davis

This paper presents a comprehensive control oriented battery model. Described first is an equivalent circuit based battery model which captures particular battery characteristics of control interest. Then, the model categorizes the battery dynamics based on their different time constants (transient, long-term, life-time). This model uses a 2-D map representing the temperature and state-of-charge dependent model parameters. Also, the model uses new battery state-of-charge and state-of-health definitions that are more practical for a real battery management system. Battery testing and simulation on various types of batteries and use scenarios was completed to validate that the model is easy to parameterize, computationally efficient and of adequate accuracy.

TuBT5	Tent B
Bio-Medical and Bio-Mechanical Systems (Contributed session)	
Chair: Leonessa, Alexander	Virginia Tech.
Co-Chair: Artemiadis, Panagiotis	Arizona State Univ.

13:30-13:50	TuBT5.1

Robot-Guided Sheaths (RoGS) for Percutaneous Access to the Pediatric Kidney: Patient-Specific Design and Preliminary Results, pp. 1530-1534

Morimoto, Tania	Stanford Univ.
Hsieh, Michael	Stanford Univ.
Okamura, Allison	Stanford Univ.

Robot-guided sheaths consisting of pre-curved tubes and steerable needles are proposed to provide surgical access to locations deep within the body. In comparison to current minimally invasive surgical robotic instruments, these sheaths are thinner, can move along more highly curved paths, and are potentially less expensive. This paper presents the patient-specific design of the pre-curved tube portion of a robot-guided sheath for access to a kidney stone; such a device could be used for delivery of an endoscope to fragment and remove the stone in a pediatric patient. First, feasible two-dimensional paths were determined considering workspace limitations, including avoidance of the ribs and lung, and minimizing collateral damage to surrounding tissue by leveraging the curvatures of the sheaths. Second, building on prior work in concentric-tube robot mechanics, the mechanical interaction of a two-element sheath was modeled and the resulting kinematics was demonstrated to achieve a feasible path in simulation. In addition, as a first step toward three-dimensional planning, patient-specific CT data was used to reconstruct a three-dimensional model of the area of interest.

13:50-14:10	TuBT5.2

Development of a Master-Slave Robotic System for Mri-Guided Intracardiac Interventions, pp. 1535-1542

Salimi, Amirhossein	Univ. of Houston
Ramezanifar, Amin	Univ. of Houston
Mohammadpour, Javad	Univ. of Georgia
Grigoriadis, Karolos M.	Univ. of Houston

Restricted space inside the magnetic resonance imaging (MRI) scanner bore prevents surgeons to directly interact with the patient during MRI-guided procedures. This motivates the development of a robotic system that can act as an interface during those interventions. In this paper, we present a master-slave robotic system as a solution to the aforedescribed issue. The proposed system consists of a commercial PHANTOM device (product of The Sensable Technologies) as the master robot and an MRI-compatible patient-mounted parallel platform (that we name ROBOCATH) designed to serve as the slave mechanism inside the scanner bore. We present in this paper the design principles for the platform, as well as the PID control design for the system. We use our experimental setup to evaluate the performance of the system by examining the effectiveness of the slave platform in tracking the reference trajectories generated by the master robot.

14:10-14:30	TuBT5.3

Beyond User-Specificity for EMG Decoding Using Multiresolution Muscle Synergy Analysis, pp. 1543-1548

Ison, Mark	Arizona State Univ.
Artemiadis, Panagiotis	Arizona State Univ.

Electromyographic (EMG) processing is a vital step towards converting noisy muscle activation signals into robust features that can be decoded and applied to applications such as prosthetics, exoskeletons, and human-machine interfaces. Current state of the art processing methods involve collecting a dense set of features which are sensitive to many of the intra- and inter- subject variability ubiquitous in EMG signals. As a result, state of the art decoding methods have been unable to obtain subject independence. This paper presents a novel multiresolution muscle synergy (MRMS) feature extraction technique which represents a set of EMG signals in a sparse domain robust to the inherent variability of EMG signals. The robust features, which can be extracted in real time, are used to train a neural network and demonstrate a highly accurate and user-independent classifier. Leave-one-out validation testing achieves mean accuracy of 81.9 and area under the receiver operating characteristic curve (AUC), a measure of overall classifier performance over all possible thresholds, of 92.4. The results show the ability of sparse MRMS features to achieve subject independence in decoders, providing opportunities for large-scale studies and more robust EMG-driven applications.

14:30-14:50	TuBT5.4

Development of Electromagnetic Stimulation System As Treatment for Muscle Activation, pp. 1549-1553

Jaramillo, Paola	Virginia Tech.
Shoemaker, Adam	Virginia Tech.
Burks, William	Virginia Tech.
Tran, Michelle	Virginia Tech.
Leonessa, Alexander	Virginia Tech.

The presented work addresses the implementation of electromagnetic stimulation with feedback control. Preliminary testing is conducted as a proof of principle to evaluate the feasibility of the experimental system for future in vitro experiments on mice muscle. Therefore, this study focuses on applying a Proportional-Integral controller to carry out contractions of a BioMetal Fiber based on set trajectories specified to the control algorithm. The experimental setup captures the instantaneous position of the BioMetal Fiber, which is used as feedback and modulated via high frequency electromagnetic fields. Consequently, the effectiveness of the controller and the two-coil electromagnetic system are evaluated to develop improved strategies for system tracking.

14:50-15:10	TuBT5.5

Design and Modeling of a Series Elastic Element for Snake Robots, pp. 1554-1558

Rollinson, David	Carnegie Mellon Univ.
Ford, Steven	Carnegie Mellon Univ.
Brown, H. Benjamin	Carnegie Mellon Univ.
Choset, Howie	Carnegie Mellon Univ.

In this work, we detail the design, fabrication, and initial modeling of a compact, high-strength series elastic element designed for use in snake robots. The spring achieves its elasticity by torsionally shearing a rubber elastomer that is bonded to two rigid plates, and it is able to achieve mechanical compliance and energy storage that is an order of magnitude greater than traditional springs. Its novel design features a tapered conical cross-section that creates uniform shear stress in the rubber, improving the ultimate strength. Tests show that the torque-displacement profile of these springs is approximately linear, and initial results are reported on creating more accurate models that account for the element's hysteresis and viscoelastic properties. Low bandwidth force control is demonstrated by measuring the element's torsional deflection to estimate the torque output of one of our snake robot modules.

15:10-15:30	TuBT5.6

Dynamic Modeling of a Compliant Tail-Propelled Robotic Fish, pp. 1559-1567

Kopman, Vladislav	Pol. Inst. of New York Univ.
Laut, Jeffrey	Pol. Inst. of New York Univ.
Porfiri, Maurizio	Pol. Inst. of NYU
Acquaviva, Francesco	Pol. di Bari
Rizzo, Alessandro	Pol. Inst. of NYU

This paper presents a dynamic model for a class of robotic fish propelled by a tail with a flexible fin. The robot is comprised of a rigid frontal link acting as a body and a rear link serving as the tail. The tail includes a rigid component, hinged to the body through a servomotor, which is connected to a compliant caudal fin whose underwater vibration induces the propulsion. The robot's body dynamics is modeled using Kirchhoff's equations of motion of bodies in quiescent fluids, while its tail motion is described with Euler-Bernoulli beam theory, accounting for the effect of the encompassing fluid through the Morison equation. Simulation data of the model is compared with experimental data. Applications of the model include simulation, prediction, design optimization, and control.

TuBT6	Room 134

Control, Monitoring, and Energy Harvesting of Vibratory Systems: Energy Harvesting (Invited session)

Chair: Zuo, Lei	Stony Brook Univ. - SUNY
Co-Chair: Kajiwara, Itsuro	Hokkaido Univ.
Organizer: Zuo, Lei	Stony Brook Univ. - SUNY
Organizer: Tang, Jiong	Univ. of Connecticut
Organizer: Sipahi, Rifat	Northeastern Univ.
Organizer: Caruntu, Dumitru	Univ. of Texas Pan American
Organizer: Nishimura, Hidekazu	Keio Univ.
Organizer: Kajiwara, Itsuro	Hokkaido Univ.

13:30-13:50	TuBT6.1

Ocean Wave Energy Converters and Control Methodologies (I), pp. 1568-1577

Xie, Jingjin	Stony Brook Univ.
Zuo, Lei	Stony Brook Univ. - SUNY

Technologies on extracting energy from the ocean wave have been explored for centuries and are still undergoing with challenges. In this paper, the origin of ocean wave and its

mathematical models are introduced. The features of current

mainstream ocean wave energy converters (OWEC), including point absorber, oscillating water column (OWC), attenuator and wave topping, are briefly reviewed. The corresponding hydrodynamics and control strategies are analyzed in a comprehensive manner thereafter. Optimal conditions for maximum power absorption are introduced with relevant mathematical modeling and derivations. Noticeably, since some of the control strategies for point absorber share a fundamental basis with other control approaches for some different type of OWECs, it is given more exposure in this article first. Other strategies for various OWECs are reviewed subsequently.

13:50-14:10 TuBT6.2

Research on Resonant Frequency and Output Power of Piezoelectric Energy-Harvesting Micro-Device (I), pp. 1578-1584

Gao, Yuji — Tianjin Univ.
Leng, Yong-gang — Tianjin Univ.
Shen, Linchen — China Agricultural Univ.
Guo, Yan — Tianjin Univ.

A vibration energy harvester is typically composed of a spring–mass system, with the advantage of high energy density, simple structure and easily being miniaturized. Recently, impact of cantilever beam's structural parameters and cross-section shape on energy-harvesting micro-device is concerned and investigated in this paper, so as to study its performance of energy harvesting to meet the needs of low resonant frequency and maximum output power. The effect of a cantilever beam's structure dimensions as well as quality of the mass on the device's resonance frequency and maximum output power can be detected through formula computing. Further study on effect of a cantilever beam's cross-section shape has also been worked out. According to the simulation experimental results gained from ANSYS with appropriate parameters defined by theoretical derivation, we manage to receive concordant conclusions. To receive a better performance of the energy harvester, we should choose a shorter, wider and thicker cantilever beam with rectangular cross-section and heavier mass at its end. However, to meet the requirement of low resonant frequency for piezoelectric vibration energy harvesting, we still need to define either an upper or a lower limit while choosing parameters of the device.

14:10-14:30 TuBT6.3

The Application of Electrode Design in Vibrating Piezoceramic Plate for Energy Harvesting System (I), pp. 1585-1594

Huang, Yu-Hsi — National Taiwan Univ. of Science and Tech.
Chao, Ching-Kong — National Taiwan Univ. of Science and Tech.
Chou, Wan-Ting — National Taiwan Univ. of Science and Tech.
Ma, Chien-Ching — National Taiwan Univ.

The energy harvesting system of piezoceramic plate is studied on the electrode configuration to improve the electromechanical transferring efficiency. The piezoceramic plate is used to perform the vibration characteristics by experimental measurements and finite element method (FEM). Thereafter, the dynamic characteristics and the electromechanical coupling efficiency of the piezoelectric energy harvesting system are studied by the electrode design method of the piezoceramic plate. Several experimental techniques are used to measure the dynamic characteristics of piezoceramic plate. First, the full-filed optical technique, amplitude-fluctuation electronic speckle pattern interferometry (AF-ESPI), can measure simultaneously the resonant frequencies and mode shapes for out-of-plane and in-plane vibrations. Second, the pointwisely measuring system, laser Doppler vibrometer (LDV), can obtain resonant frequencies by dynamic signal swept-sine analysis. Third, the correspondent in-plane resonant frequencies and anti-resonant frequencies are obtained by impedance analysis. The experimental results of vibration characteristics are verified with numerical calculations. Besides the dynamic characteristics of piezoceramic plates are analyzed in converse piezoelectric effect, the direct piezoelectric effect of piezoceramic plates are excited by shaker to generate the electric voltage. It has excellent consistence between resonant frequencies and mode shapes on the vibration characteristics by experimental measurements and finite element numerical calculations. In this study, the Electrical Potential Gradient (EPG) calculated by FEM is proposed to evaluate the electromechanical coupling efficiency of piezoceramic plate on the specific vibration mode. The correspondent electrode configuration, which is designed by EPG, can produce the best electromechanical transfer both in direct and converse piezoelectric effects. It is concluded that the vibration characteristics of piezoelectric materials have excellent consistence determined by experimental measurements and FEM.

14:30-14:50 TuBT6.4

Further Application of Stochastic Resonance for Energy Harvesting (I), pp. 1595-1601

Su, Dongxu — Univ. of Tokyo
Nakano, Kimihiko — Univ. of Tokyo
Hu, Honggang — The Univ. of Tokyo
Cartmell, Matthew P — Univ. of Sheffield
Ohori, Masanori — The Univ. of Tokyo
Zheng, Rencheng — The Univ. of Tokyo

In addition to the wide range of applications of stochastic resonance in the field of signal processing, the phenomenon has also been investigated as an effective tool for enhancing vibrational energy harvesting. This paper proposes a hypothetical method for achieving stochastic resonance and increasing the available energy from external ambient vibration. In order to illustrate this proposal, a bistable mechanical system is proposed to study the feasibility by theoretical analysis. The amount of available energy and the energy consumed to produce the small-scale additional force is analyzed through numerical simulations. It is shown that the proposed method can significantly enhance the harvested vibrational energy.

14:50-15:10 TuBT6.5

Damage Identification in Collocated Structural Systems Using Structural Markov Parameters (I), pp. 1602-1611

Bighamian, Ramin — Univ. of Maryland
Mirdamadi, Hamid Reza — Isfahan Univ. of Tech.
Hahn, Jin-Oh — Univ. of Maryland

This paper presents a novel approach to damage identification in a class of collocated multi-input multi-output structural systems. In the proposed approach, damage is identified via the structural Markov parameters obtained from a system identification procedure, which is in turn exploited to localize and quantify damage by evaluating relative changes occurring in the mass and stiffness matrices associated with the structural system. To this aim, an explicit relationship between structural Markov parameters versus mass and stiffness matrices is developed. The main strengths of the proposed approach are that it is capable of quantitatively identifying the occurrence of multiple damages associated with both mass and stiffness characteristics in the structural system, and it is computationally efficient in that it is solely based on the structural Markov parameters but does not necessitate costly calculations related to natural frequencies and mode shapes, making it highly attractive for structural damage detection and health monitoring applications. Numerical examples are provided to demonstrate the validity and effectiveness of the proposed approach.

15:10-15:30 TuBT6.6

Development of a Variable Electromotive-Force Generator with an Active Control System (I), pp. 1612-1621

Zhu, Weidong — Univ. of Maryland, Baltimore

County

Goudarzi, Navid — Univ. of Maryland, Baltimore County

Wang, Xuefeng — Univ. of Maryland, Baltimore County

Kendrick, Phillip — Univ. of Maryland, Baltimore County

A variable electromotive-force generator (VEG), which is a modified generator with an adjustable overlap between the rotor and the stator, is proposed to improve the efficiency and/or expand the operational range of a conventional generator, with particular applications to wind turbines, hybrid vehicles, and so on. A mathematical model of the VEG is developed, and a novel prototype is designed and fabricated. The performance of the VEG with the active control system, which adjusts the overlap ratio based on the desired output power at different input speeds, is theoretically and experimentally studied. The results show that reducing the overlap between the rotor and the stator of the generator at low speeds results in a reduced torque loss of the generator and an increased rotational speed of the generator rotor.

TuBT7	Room 138
Variable Structure/ Sliding-Mode Control (Contributed session)	
Chair: Tomizuka, Masayoshi	Univ. of California, Berkeley
Co-Chair: Choi, Changrak	MIT

13:30-13:50 — TuBT7.1

Robust Control of an Hvac System Via a Super-Twisting Sliding Mode Technique, pp. 1622-1627

Kianfar, Kaveh — Simon Fraser Univ.

Izadi-Zamanabadi, Roozbeh — Danfoss A/S

Saif, Mehrdad — Univ. of Windsor

This paper presents design and implementation of a super twisting sliding mode control for superheat temperature and evaporating temperature of refrigerant fluid in an evaporator of HVAC (Heating-Ventilation and Air Conditioning)-Refrigeration system. Based on a nonlinear model of the evaporator two control approaches are presented. The first approach is based on a Multi-Input Multi Output (MIMO) system in which there are two control inputs; inlet mass flow and outlet mass flow rate, and the outputs are the length of two phase flow and evaporating temperature of refrigerant. The second approach considers the system as a Single input single output (SISO) one and by using inlet mass flow, superheat temperature is controlled. In the first approach, by implementing a feedback linearization method the two control inputs are decoupled. By decoupling the effects of both inputs the two state variables of system are controlled separately and effectively. By applying sliding mode control robustness against the disturbances and uncertainties is guaranteed. Super-twisting algorithm is applied as a remedy for chattering problem in classical sliding mode control and achieving finite time convergence. Controller and model of systems are simulated using MATLAB and Simulink. The results of simulations show the effectiveness of designed controller in presence of uncertainties.

13:50-14:10 — TuBT7.2

Optimal Sliding Mode Gaussian Controller for Hydropower Plant with Grid Dynamics, pp. 1628-1634

Rittenhouse, Benjamin — Pennsylvania State Univ.

Sinha, Alok — Penn State Univ.

This paper examines the performance of an optimal sliding mode Gaussian (OSG) controller for the regulation of a hydropower plant implemented in the modeling program SIMSEN. The controller is designed to regulate grid frequency and includes the dynamics of the wicket gate servo system, turbine, and grid. Simulation results for OSG control are compared to those of more traditional LQG and PI controllers. Simulation shows that OSG control provides superior performance for the nominal system and for the system with parametric uncertainties.

14:10-14:30 — TuBT7.3

Model Predictive Sliding Mode Control — for Constraint Satisfaction and Robustness, pp. 1635-1644

Wang, Yizhou — Univ. of California at Berkeley

Chen, Wenjie — Univ. of California at Berkeley

Tomizuka, Masayoshi — Univ. of California, Berkeley

Alsuwaidan, Badr — King Abdulaziz City for Science and Tech.

A novel combination of model predictive control (MPC) and sliding mode control (SMC) is presented in this paper. The motivation is to inherit the ability to explicitly deal with state and input constraints from MPC, and the good robustness property from SMC. The design of the finite-time optimal control problem and the conditions for the persistent feasibility and the closed-loop stability are discussed. Simulation results are shown to demonstrate the nominal and robust performance of the proposed control algorithm.

14:30-14:50 — TuBT7.4

Control of Inverted Pendulum Using Only Vertical Force through Harmonic Oscillation, pp. 1645-1654

Choi, Changrak — MIT

Control of an inverted pendulum using horizontal force (e.g. cart-pole) is a well-established problem. However, there is no work in the literature that addresses controlling an inverted pendulum using only vertical force without horizontal movement. In this paper, control algorithm is presented that can control the inverted pendulum via only vertical force within the operating range of the given system. In the process, the dynamic stabilizing effect of vertical harmonic oscillation acting on inverted pendulum is exploited and previous works on the analysis of the stabilizing effect is utilized. The result is a nonlinear controller that combines sliding mode and energy shaping control which is capable of stabilizing the pendulum upright as well as at any titled angle within the region of attraction described. This is done for pendulum starting at any initial angle while maintaining vertical movement of the inverted pendulum within the prescribed space limit.

14:50-15:10 — TuBT7.5

Backward-Euler Discretization of Second-Order Sliding Mode Control and Super-Twisting Observer for Accurate Position Control, pp. 1655-1662

Xiong, Xiaogang — Kyushu Univ.

Kikuuwe, Ryo — Kyushu Univ.

Yamamoto, Motoji — Kyushu Univ.

This paper introduces an accurate position control algorithm based on Backward-Euler discretization of a second-order sliding mode control (SOSMC) and the super-twisting observer (STO). This position control algorithm does not produce numerical chattering, which has been known to be a major drawback of explicit implementation of SOSMC and STO. It is more accurate than the conventional PID control that is also free of chattering. In contrast to conventional Backward-Euler discretization schemes of SOSMC and STO, the presented discretization method does not require any special solvers for computation. The accuracy and implementation of this algorithm are illustrated by simulations.

15:10-15:30 — TuBT7.6

*A Fixed Time Sliding Mode Observer for Flux and Load in Induction Motors**

Sánchez-Torres, Juan Diego — CINVESTAV-IPN GDL

Rubio Astorga, Guillermo — CINVESTAV-IPN GDL

Cañedo Catañeda, José Manuel — CINVESTAV-IPN GDL

Loukianov, Alexander G. — CINVESTAV IPN GDl

WeAT1	Paul Brest East
Intelligent Transportation Systems (Invited session)	
Chair: Langari, Reza	Texas A&M Univ.
Co-Chair: Kolodziej, Jason	Rochester Inst. of Tech.
Organizer: Scacchioli, Annalisa	New York Univ.
Organizer: Kolodziej, Jason	Rochester Inst. of Tech.
Organizer: Canova, Marcello	The Ohio State Univ.
Organizer: Shahbakhti, Mahdi	Michigan Tech. Univ.
Organizer: Yan, Fengjun	McMaster Univ.
Organizer: Hall, Carrie	Purdue Univ.

10:15-10:35 WeAT1.1

Digital Effects and Delays in Connected Vehicles: Linear Stability and Simulations (I), pp. 1663-1672

Qin, Wubing B.	Univ. of Michigan, Ann Arbor
Orosz, Gabor	Univ. of Michigan

To improve the ride quality in connected vehicle platoons, information about the motion of the leader can be transmitted using vehicle-to-vehicle (V2V) communication and such information can be incorporated in the controllers of the following vehicle. However, according to the current V2V standards, dedicated short range communication (DSRC) devices transmit information every 100 ms which introduces time delays into the control loops. In this paper we study the effects of these time delays on the dynamics of vehicle platoons subject to digital control and derive conditions for plant stability and string stability. It is shown that when the time delay exceeds a critical value, no gain combination can stabilize the system. Our results have important implications on connected vehicle design.

10:35-10:55 WeAT1.2

Self-Reconfigurable Control System for Autonomous Vehicles (I), pp. 1673-1678

Shoureshi, Rahmat	Univ. of Denver
Lim, Sun-Wook	New York Inst. of Tech.
Aasted, Christopher	Harvard Medical School / Boston Children's Hospital

This paper presents a reconfigurable control design technique that integrates a robust feedback and an iterative learning control (ILC) scheme. This technique is applied to develop vehicle control systems that are tolerant to failures due to malfunctions or damages. The design procedure includes solving the robust performance condition for a feedback controller through the use of μ-synthesis that also satisfies the convergence condition for the iterative learning control rule. The effectiveness of the proposed approach is verified by simulation experiments using a Radio Controlled (R/C) model airplane. The methods presented in this paper can be applied to design of global intelligent control systems to improve the operating characteristics of vehicle and increase safety and reliability.

10:55-11:15 WeAT1.3

A Stackelberg Game Theoretic Driver Model for Merging (I), pp. 1679-1686

Yoo, Je Hong	Texas A&M Univ.
Langari, Reza	Texas A&M Univ.

Merging is one of the important issues in studying roadway traffic. Merging disturbs the mainline of traffic, which reduces the efficiency or capacity of the highway system. In this paper, we have considered the application of a Stackelberg game theory to a driver behavior model in a merging situation. In this model, the so-called payoffs that reflect the drivers' aggressiveness affect the decision to proceed to merge and whether to accelerate or decelerate in the game theoretic framework. These merging behaviors in turn impact the mainline traffic, which may lead to a variety of influences, such as collisions or reduced roadway throughput. Consequently, this impact depends on the level of aggressiveness of the driver merging in and those in the mainline, which results in both longitudinal and lateral disturbances in the mainline due to their interaction.

11:15-11:35 WeAT1.4

Hybrid Powertrain Optimization with Real-Time Traffic Information (I), pp. 1687-1696

Mohd Zulkefli, Mohd Azrin	Univ. of Minnesota
Zheng, Jianfeng	Univ. of Minnesota
Sun, Zongxuan	Univ. of Minnesota
Liu, Henry	Univ. of Minnesota

Combining hybrid powertrain optimization with traffic information has been researched before, but tradeoffs between optimality, driving-cycle sensitivity and speed of calculation have not been cohesively addressed. Optimizing hybrid powertrain with traffic can be done through iterative methods such as Dynamic Programming (DP), Stochastic-DP and Model Predictive Control, but high computation load limits their online implementation. Equivalent Consumption Minimization Strategy (ECMS) and Adaptive-ECMS were proposed to minimize computation time, but unable to ensure real-time charge-sustaining-operation (CS) in transient traffic environment. Others show relationship between Pontryagin's Minimum Principles (PMP) and ECMS, but iteratively solve the CS-operation problem offline. This paper proposes combining PMP's necessary conditions for optimality, with sum-of State-Of-Charge-derivative for CS-operation. A lookup table is generated offline to interpolate linear mass-fuel-rate vs net-power-to-battery slopes to calculate the equivalence ratio for real-time implementation with predicted traffic data. Maximum fuel economy improvements of 7.2% over Rule-Based is achieved within a simulated traffic network.

11:35-11:55 WeAT1.5

Stability of Connected Vehicle Platoons with Delayed Acceleration Feedback (I), pp. 1697-1706

Ge, Jin I.	Univ. of Michigan, Ann Arbor
Avedisov (Jr.), Sergei S.	Univ. of Michigan, Ann Arbor
Orosz, Gabor	Univ. of Michigan

Wireless vehicle-to-vehicle communication technologies such as the dedicated short range communication (DSRC) may be used to assist drivers in sensing and responding to impalpable information such as the precise acceleration of vehicles ahead. In this paper, we investigate the impact of delayed acceleration feedback on traffic flow using a nonlinear car-following model. It is shown that acceleration feedback can improve the stability of uniform flow, though excessive acceleration feedback leads to undesired high frequency oscillations. Additionally, time delays in the communication channel may shrink the stable domain by introducing mid-frequency oscillations. Finally, we show that one may stabilize vehicle platoons using delayed acceleration feedback even in cases when finite driver reaction time would destabilize the system. The results provide an understanding of platoon dynamics with delayed acceleration feedback and allow the design of more robust cruise control systems with increased driver comfort in connected vehicle environment.

11:55-12:15 WeAT1.6

Accounting for Parametric Model Uncertainty in Collision Avoidance for Unmanned Vehicles Using Sparse Grid Interpolation, pp. 1707-1714

Noble, Sarah	United States Naval Acad.
Esposito, Joel	US Naval Acad.

In this paper we present an enhancement of model-based trajectory selection algorithms – a popular class of collision avoidance techniques for autonomous ground vehicles. Rather than dilate a set of individual candidate trajectories in an ad hoc way to account for uncertainty, we generate a set of trajectory clouds – sets of states that represent possible future poses over a product of intervals representing uncertainty in the model parameters, initial conditions and actuator commands. The clouds are generated using the sparse-grid interpolation method which is both error-controlled and computationally efficient. The approach is implemented on a differential drive vehicle.

WeAT2	Room 123
Robotic Manipulators (Contributed session)	
Chair: Krovi, Venkat N.	SUNY Buffalo
Co-Chair: Mascaro, Stephen	Univ. of Utah

10:15-10:35 WeAT2.1

Optimal Control Algorithm for Multi-Input Binary-Segmented SMA Actuators Applied to a Multi-DOF Robot Manipulator, pp. 1715-1722

Mollaei, Mohammadreza — Univ. OF UTAH
Mascaro, Stephen — Univ. of Utah

In this paper, we present an optimal design and control algorithm for multi-input binary-segmented Shape Memory Alloy (SMA) actuator arrays applied to a multi-degree-of-freedom (DOF) robot manipulator as it tracks a desired trajectory. The multi-DOF manipulator used for this paper is a 3-DOF-robot finger. A multi-input binary-segmented SMA actuator drives each DOF. SMA wires are embedded into a compliant vessel, such that both electric and fluidic (hot/cold) input can be applied to the actuators. By segmenting the SMA actuators, each segment can be controlled in a binary fashion (fully contracted/extended) to create a set of discrete displacements for each joint of the manipulator. To design the number of segments and length of each segment, an algorithm is developed to optimize the workspace. To optimize the workspace, it is desired to have a uniform distribution of reachable points in Cartesian space. Moreover, the number of neighbors (points that can be reached just by one control command from the current configuration) and the computational cost are important in workspace optimization. Graph theory search techniques based on the A* algorithm are employed to develop the control algorithm. A path-cost function is proposed to optimize the cost, which is a combination of actuation time, energy usage, and kinematic error. The kinematic error is estimated as the deviation between the actual and desired trajectory. The performance of the search algorithm and cost function are validated through simulation.

10:35-10:55 WeAT2.2

Design of Input Shaping Control for Planar Parallel Manipulators, pp. 1723-1731

Sathia Narayanan, Madusudanan — School of Engineering, Univ. at Buffalo
Krovi, Venkat N. — SUNY Buffalo

Parallel manipulators are well known for superior stiffness, higher accuracy, lower inertia and faster response compared to the serial counterparts and hence is widely used for high-speed machining and heavy load applications. However, controller limitations as well as design constraints can result in unoptimized designs causing unsettling residual vibrations at the end effector and limit their applications. Though many have discussed vibration attenuation by improving the structural design, augmenting with redundant sensors/ dampers and advanced feedback control methods for serial and mobile manipulators, very few investigated such techniques for parallel manipulators (PM). In this manuscript, we evaluate a specific type of feed-forward technique for planar PM. Lagrangian based dynamic models of platform manipulators and a simple trajectory level proportional derivative control will be used with the gains tuned to force oscillations at the end effector to ensure stability with bounded constraints on controller gains. We will then demonstrate the applicability of basic input shapers for PM based on computation of natural frequencies and damping ratio for each mode, and resulting improvements in terms of appropriate performance measures.

10:55-11:15 WeAT2.3

Maneuver Based Design of Passive-Assist Devices: A Comparison of Parallel and Serial Systems, pp. 1732-1741

Brown, W. Robert — Univ. of Michigan
Ulsoy, A. Galip — Univ. of Michigan

A comparison of serial, parallel, and dual Passive Assist Devices (PADs) designed using energy minimization based on a known maneuver is presented. Implementation of a PAD can result in an improvement in system performance with respect to efficiency, reliability, and/or safety. In previous work we demonstrated this concept experimentally on a single link robot arm augmented with a torsional spring in parallel. Here we show that the concept can extended to serial and dual systems as well. To make the optimization converge more quickly we introduce a new initial design using a weighted force displacement curve fit. We provide engineering insight into why different types of PADs perform differently depending on the maneuver and offer guidelines on how to select a specific type based on the application. Finally, we demonstrate this design process and selection procedure on a 3-link manipulator arm and show that a combination of parallel and dual PADs could reduce energy consumption by up to 78%.

11:15-11:35 WeAT2.4

Evaluation and Design of Manipulators Based on a Dynamic Accuracy Index Considering Task-Directions, pp. 1742-1750

Kai, Yoshihiro — Tokai Univ.

Some manipulation tasks have directions of end-effector acceleration of a manipulator and directions for which dynamic accuracy is required in the motion. This paper proposes an index (DAIT: Dynamic Accuracy Index for Task-directions) that allows us to evaluate the dynamic accuracy of manipulators considering the task-directions. Firstly, we derive the DAIT. Secondly, we evaluate some postures of a 2-degrees of freedom (DOF) planar manipulator on the basis of some indices that have been proposed (condition number, dynamic manipulability measure and task compatibility) and the DAIT, respectively. Thirdly, we show a manipulator's design example based on the DAIT. Finally, from the evaluation and design results, we discuss the usefulness of the DAIT in determining the suitable postures of the manipulator for a given task and in designing the suitable manipulators for a given task.

11:35-11:55 WeAT2.5

Kinematic Synthesis of Minimally Actuated Multi-Loop Planar Linkages with Second Order Motion Constraints for Object Grasping (I), pp. 1751-1758

Soh, Gim Song — Singapore Univ. of Tech. and Design
Robson, Nina — California State Univ. Fullerton

In this paper, we consider the dimensional synthesis of one degree-of-freedom multi-loop planar linkages such that they do not violate normal direction and second order curvature constraints imposed by contact with objects. Our goal is in developing minimally actuated multi-loop mechanical devices for human-robot interaction, that is, devices whose tasks will happen in a human environment.

Currently no systematic method exists for the kinematic synthesis of robotic fingers that incorporate multi-loop kinematic structure with second order task constraints, related to curvature. We show how to use these contact and curvature effects to formulate the synthesis equations for the design of a planar one-degree-of-freedom six-bar linkage. An example for the design of a finger that maintains a specified contact with an object, for an anthropomorphic task, is presented at the end of the paper.

It is important to note, that the theoretical foundation presented in this paper, assists in solving some of the open problems of this field, providing preliminary results on the synthesis of kinematic chains with multi- loop topology and the use of novel task specifications that incorporate curvature constraints with future applications in grasping and object manipulation.

11:55-12:15	WeAT2.6

A Feed Forward Neural Network for Solving the Inverse Kinetics of Non-Constant Curvature Soft Manipulators Driven by Cables, pp. 1759-1768

Giorelli, Michele	Scuola Superiore Sant'Anna
Renda, Federico	Scuola Superiore Sant'Anna
Ferri, Gabriele	Scuola Superiore Sant'Anna
Laschi, Cecilia	Scuola Superiore Sant'Anna

The solution of the inverse kinetics problem of soft manipulators is essential to generate paths in the task space to perform grasping operations. To address this issue, researchers have proposed different iterative methods based on Jacobian matrix. However, although these methods guarantee a good degree of accuracy, they suffer from singularities, long-term convergence, parametric uncertainties and high computational cost. To overcome intrinsic problems of iterative algorithms, we propose here a neural network learning of the inverse kinetics of a soft manipulator. To our best knowledge, this represents the first attempt in this direction. A preliminary work on the feasibility of the neural network solution has been proposed for a conical shape manipulator driven by cables. After the training, a feed-forward neural network (FNN) is able to represent the relation between the manipulator tip position and the forces applied to the cables. The results show that a desired tip position can be achieved quickly with a degree of accuracy of 0.73% relative average error with respect to total length of arm.

WeAT3	Tent A

Piezoelectric Actuation and Nanoscale Control (Contributed session)

Chair: Zou, Qingze	Rutgers, the State Univ. of New Jersey
Co-Chair: Oldham, Kenn	Univ. of Michigan

10:15-10:35	WeAT3.1

Flatness-Based Open Loop Command Tracking for Quasistatic Microscanners, pp. 1769-1773

Janschek, Klaus	Tech. Univ. Dresden
Schroedter, Richard	Fraunhofer Inst. for Photonic Microsystems, Dresden
Sandner, Thilo	Fraunhofer Inst. for Photonic Microsystems, Dresden

This paper describes a nonlinear command tracking scheme for an electrostatic laser scanning micromirror assembly. The results are based on an innovative gimballed comb transducer concept developed at the Fraunhofer Institute for Photonic Microsystems. The outer mirror axis is designed as a Staggered Vertical Comb (SVC) in out-of-plane configuration and it shall provide a quasistatic operation with large deflection angles for triangular trajectories. The challenges for trajectory design and open loop command tracking are determined by the inherently nonlinear transducer characteristics and the lightly damped mass-spring dynamics. In this paper a flatness-based trajectory design is presented that considers the nonlinear transducer dynamics as well as the nonlinear elastic mechanical suspension with model parameters derived from ANSYS analysis. The paper discusses design constraints and detailed design considerations and it shows proof of concept performance results based on experimental verification with a real microscanner assembly.

10:35-10:55	WeAT3.2

Two Degree-Of-Freedom Hysteresis Compensation for a Dynamic Mirror with Antagonistic Piezoelectric Stack Actuation, pp. 1774-1783

Mynderse, James A.	Lawrence Tech. Univ.
Chiu, George T.-C.	Purdue Univ.

A methodology for designing a low-computation, high-bandwidth strategy for closed-loop control of a hysteretic system without a priori knowledge of the desired trajectory is presented. The resulting two degree-of-freedom hysteresis control strategy is applied to a dynamic mirror with antagonistic piezoelectric stack actuation. Hysteresis compensator is performed by a finite state machine switching polynomials for hysteresis inversion based on the input signal slope. Residual error after hysteresis compensation is corrected by an LQR feedback controller. Experimental results demonstrate effectiveness of the hysteresis compensator and closed-loop system under the proposed hysteresis control strategy. For the triangular input signal tested, the closed-loop system achieves a 91.5% reduction in hysteresis uncertainty with 60 kHz sample rate.

10:55-11:15	WeAT3.3

Iterative-Control-Based High-Speed Direct Mask Fabrication Via Ultrasonic-Vibration-Assisted Mechanical Plowing, pp. 1784-1791

Wang, Zhihua	Rutgers, the State Univ. of New Jersey
Zou, Qingze	Rutgers, the State Univ. of New Jersey

Mechanical indentation and plowing is one of the most widely used methods in probe-based nanolithography. Compared to other probe-based nanolithography techniques such as the Dip-pen and the milliped, mechanical plowing is not restrictive to conductive materials and/or soft materials. However, like other probe-based nanolithgraphy techniques, the low-throughput has hindered the implementation of this technique in practices. The fabrication throughput, although can be increased via parallel-probe, is ultimately limited by the tracking precision of the probe relative to the sample during the plowing process. In this paper, a new iterative learning control technique is proposed and utilized to account for the adverse effects encountered in high-speed, large-range mechanical plowing nanolithography, including the hysteresis, the vibrational dynamics, and the cross-axis dynamics-coupling effects. Moreover, vertical (normal) ultrasonic vibration of the cantilever is introduced during the fabrication process to improve the fabrication quality. This approach is implemented to directly fabricate patterns on a mask with a tungsten layer deposited on a silicon dioxide substrate. The experimental results demonstrated that a relatively large-size pattern of four grooves (20 mum in length) can be fabricated at a high-speed of sim5 mm/sec, with the line width and line depth at sim95~nm and 2~nm, respectively. A fine pattern of the word `NANO' is also achieved at the speed of sim5 mm/sec. Such a high-speed direct lithography of mask with nanoscale line width and depth points the use of mechanical-plowing technique in strategic-important applications such as mask lithography for semiconductor industry.

11:15-11:35	WeAT3.4

Design of a Piezoelectric Poly-Actuated Linear Motor, pp. 1792-1801

Tsukahara, Shinichiro	Sumitomo Heavy Industries, Ltd.
Penalver-Aguila, Lluis	Massachusetts Inst. of Tech.
Torres, James	Massachusetts Inst. of Tech.
Asada, H. Harry	Massachusetts Inst. of Tech.

Design and analysis for an efficient and force dense piezoelectric poly-actuated linear motor is presented. A linear motor is constructed with multiple piezoelectric actuator units engaging a rod having gear teeth. The multiple piezo-units are placed along the geared rod with a particular phase difference such that a near constant force is generated regardless of the rod position by coordinating the multiple piezo-units. Rolling contact buckling mechanisms within the piezo-units provide large displacement amplification with high energy transmission and low loss properties from the piezo-units to the geared rod. This piezo-based motor has capacitive actuator characteristics which allow it to bear static loads efficiently. Furthermore, the poly-actuator architecture presented provides for scalability through modular design. First, the basic design principle describing the engagement of buckling amplification mechanisms to a phased array-shaped gear rod is presented, and the resulting force and displacement characteristics are analyzed. Design methods for creating a piezoelectric poly-actuated linear motor are then summarized. A prototype design is presented for which a maximum

mean force of 213 N, a maximum velocity of 1.125 m/s, and a force density of 41 N/kg is calculated.

11:35-11:55	WeAT3.5

An Iterative Learning Controller for High Precision Calibration of an Inertial Measurement Unit Using a Piezoelectric Platform, pp. 1802-1808

Edamana, Biju	Univ. of Michigan
Oldham, Kenn	Univ. of Michigan

A novel threshold sensing strategy for improving accuracy of a tracking controller used in calibration of an Inertial Measurement Unit (IMU) with a piezoelectric micro-actuator is presented in this paper. An asynchronous threshold sensor is hypothesized as a way to improve state estimates obtained from analog sensor measurements of micro-actuator motion. In order to produce accurate periodic signals using the proposed piezoelectric actuator and sensing arrangement, an Iterative Learning Control (ILC) is employed for control system design. Three sensing strategies: (i) an analog sensor alone with a Kalman filter, (ii) an analog sensor and threshold sensor with a Kalman filter and (iii) an analog sensor and threshold sensor with a Kalman smoother are compared in simulation. Results show that incorporating threshold sensors into the piezoelectric micro-actuation system should allow at least certain angular positions or rates to be known with much higher accuracy than from analog sensing alone, which can be useful for identifying calibration curves from the linear region of IMU operation.

11:55-12:15	WeAT3.6

Static and Dynamic Modeling of a Multi-Axis Thin-Film Piezoelectric Micro-Actuator, pp. 1809-1817

Choi, Jongsoo	Univ. of Michigan
Rhee, Choong-Ho	Univ. of Michigan, Ann Arbor
Qiu, Zhen	Univ. of Michigan
Wang, Thomas	Univ. of Michigan
Oldham, Kenn	Univ. of Michigan

Multi-axis (z, θx, θy) micro-actuators based on thin-film lead-zirconate-titanate (PZT) for use in dual axes confocal microscopy are presented with their static and dynamic models. Prototype actuators have achieved as much as 430 μm of vertical displacement and ±10º of mechanical tilting angles in both θx and θy directions in a footprint of 3.2×3.2 mm. The experimental static displacements and transient response of the actuator were used to identify residual stresses in the thin films, dimensional variance due to fabrication limitation, and damping coefficients in the model. With the identified parameters, the model predicts the static displacements of the four corners of the stage with an average absolute error of 17.4 μm over five different voltage levels and shows a reasonable agreement with the experimentally measured transient dynamic data. These results will be used to develop closed-loop controller for the system.

WeAT4	Paul Brest West
Flow and Thermal Systems (Contributed session)	
Chair: Li, Yaoyu	Univ. of Texas at Dallas
Co-Chair: Ayalew, Beshah	Clemson Univ.

10:15-10:35	WeAT4.1

Pod-Galerkin-Reduced Model Predictive Control for Radiative Drying of Coatings, pp. 1818-1826

Cao, Xiaoqing	Clemson Univ.
Ayalew, Beshah	Clemson Univ.

The process of drying coatings constitutes an important step in automotive plants. In this paper, a control scheme for infrared drying of waterborne coatings is outlined and demonstrated. The drying process model, which is described by a coupled system of a nonlinear partial differential equation for moisture content and a nonlinear ordinary differential equation for coating temperature, is first reduced to a system of nonlinear ODEs using the POD-Galerkin method. Then, a nonlinear model predictive control framework is devised to track a prescribed moisture removal profile during the drying process, while optimizing energy consumption and quality criteria. The effectiveness of the approach is demonstrated using system simulations.

10:35-10:55	WeAT4.2

Reliable Sensing of Leaks in Pipelines, pp. 1827-1836

Chatzigeorgiou, Dimitris	MIT
Wu, You	Massachusetts Inst. of Tech.
Youcef-Toumi, Kamal	Massachusetts Inst. of Tech.
Ben-Mansour, Rached	King Fahd Univ. of Petroleum & Minerals

Leakage is the major factor for unaccounted losses in every pipe network around the world (oil, gas or water). In most cases the deleterious effects associated with the occurrence of leaks may present serious economical and health problems. Therefore, leaks must be quickly detected, located and repaired. Unfortunately, most state of the art leak detection systems have limited applicability, are neither reliable nor robust, while others depend on user experience.

In this work we present a new in-pipe leak detection system, PipeGuard. PipeGuard performs autonomous leak detection in pipes and, thus, eliminates the need for user experience. This paper focuses on the detection module and its main characteristics. Detection in based on the presence of a pressure gradient in the neighborhood of the leak. Moreover, the proposed detector can sense leaks at any angle around the circumference of the pipe with only two sensors. We have validated the concepts by building a prototype and evaluated its performance under real conditions in an experimental laboratory setup.

10:55-11:15	WeAT4.3

Polymer Flow Control in Continuous Gravimetric Blenders, pp. 1837-1844

Cologni, Alberto Luigi	Univ. degli studi di Bergamo
Formentin, Simone	Univ. of Bergamo
Previdi, Fabio	Univ. degli Studi di Bergamo
Savaresi, Sergio Matteo	Pol. Di Milano

In this paper, the design of a plastic flow control system for continuous gravimetric blenders used in polymer extrusion processes is discussed. The considered plant is a blending machine that mixes four different polymers, bulks and additives. In order to pursue the desired behavior, three control objectives are considered: plastic flow estimation based on weight and screw speed measurements, plastic flow regulation for each meter and control of the recipe with mass constraints such that the mixer can always satisfy the plastic flow variation needed by the extruder. Simulation results are used to show the effectiveness of the proposed approach.

11:15-11:35	WeAT4.4

Fast, High-Fidelity Simulation of Dynamic Thermo-Fluid States in Refrigeration Systems, pp. 1845-1853

Wait, Keith	General Electric Appliances
Abbasi, Bahman	Booz Allen Hamilton
Kempiak, Michael	General Electric

A dynamic model of a heat exchanger containing a phase-changing refrigerant is presented. Due to fundamental characteristics of phase-changing fluids, the model is computationally inefficient. Remedies to this inefficiency, such as hastened computation of fluid properties, realistic heat transfer coefficient blending, and active control of oscillations in the thermodynamic state of the system are presented. These remedies are shown to minimally impact the output of the model while allowing it to execute much more quickly than real-time.

11:35-11:55	WeAT4.5

Spatio-Temporal Estimation of Wildfire Growth, pp. 1854-1861

Sharma, Balaji	Univ. of Cincinnati
Kumar, Manish	Univ. of Toledo
Cohen, Kelly	Univ. of Cincinnati

This work presents a methodology for real-time estimation of wildland fire growth, utilizing a fire growth model based on a set of partial differential equations for prediction, and harnessing concepts of space-time Kalman filtering and Proper Orthogonal Decomposition techniques towards low dimensional estimation of potentially large spatio-temporal states. The estimation framework is discussed in its criticality towards potential applications such as forest fire surveillance with unmanned systems equipped with onboard sensor suites. The effectiveness of the estimation process is evaluated numerically over fire growth data simulated using a well-established fire growth model described by coupled partial differential equations. The methodology is shown to be fairly accurate in estimating spatio-temporal process states through noise-ridden measurements for real-time deployability.

11:55-12:15	WeAT4.6

Comparison of Several Self-Optimizing Control Methods for Efficient Operation for a Chilled Water Plant, pp. 1862-1870

Mu, Baojie	The Univ. of Texas at Dallas
Li, Yaoyu	Univ. of Texas at Dallas
Seem, John E.	Johnson Controls Inc.

Self-optimizing control methods have received significant attention recently, due to the merit of nearly model-free capability of real-time optimization. Of particular interest in our study are two classes of self-optimizing control strategies, i.e. the Extremum Seeking Control (ESC) and Simultaneous Perturbation Stochastic Approximation (SPSA). Six algorithms, including dither ESC, adaptive dither ESC, switching ESC, one-measurement SPSA, and adaptive one-measurement SPSA are compared based on simulation study with a Modelcia based virtual plant of chiller-tower plant. The integral performance indices are evaluated to incorporate both transient and steady-state characteristics. Some design procedures are summarized for these self-optimizing control algorithms.

WeAT5	Tent B

Biologically-Inspired Control and Its Applications (Invited session)

Chair: Abaid, Nicole	Virginia Pol. Inst. and State Univ.
Co-Chair: Butail, Sachit	Pol. Inst. of New York Univ.
Organizer: Abaid, Nicole	Virginia Pol. Inst. and State Univ.
Organizer: Porfiri, Maurizio	Pol. Inst. of NYU

10:15-10:35	WeAT5.1

Collective Response of Zebrafish to a Mobile Robotic Fish (I), pp. 1871-1878

Butail, Sachit	Pol. Inst. of New York Univ.
Bartolini, Tiziana	NYU-Pol.
Porfiri, Maurizio	Pol. Inst. of NYU

We investigate the response of groups of zebrafish, a model social organism, to a free-swimming robotic fish. The robot has a body and tail section and moves forward by beating the tail. Steering control is achieved by offsetting the beating tail with respect to the body. The color pattern and shape of the robot are informed by visual cues known to be preferred by zebrafish. A real-time multi-target tracking algorithm uses position and velocity estimates to autonomously maneuver the robot in circular trajectories. Observables of collective behavior are computed from the fish trajectory data to measure cohesiveness, polarization, and speed of the zebrafish group in two different experimental conditions. We show that while fish are significantly less polarized in the presence of the robot with an accompanying change in average speed, there is no significant change in the degree of cohesion.

10:35-10:55	WeAT5.2

Bats versus Bugs: Collective Behavior of Prey Decreases Predation in a Biologically-Inspired Multi-Agent System (I), pp. 1879-1886

Lin, Yuan	Virginia Pol. Inst. and State Univ.
Abaid, Nicole	Virginia Pol. Inst. and State Univ.

In this paper, we establish an agent-based model to study the impact of collective behavior of a prey species on the hunting success of predators inspired by insectivorous bats and swarming insects, called 'bugs'. In the model, we consider bats preying on bugs in a three-dimensional space with periodic boundaries. The bugs follow one of the two regimes: either they swarm randomly without interacting with peers, or they seek to align their velocity directions, which results in collective behavior. Simultaneously, the bats sense their environment with a sensing space inspired by big brown bats (Eptesicus fuscus) and independently prey on bugs. We define order parameters to measure the alignment and cohesion of the bugs and relate these quantities to the cohesion and the hunting success of the bats. Comparing the results when the bugs swarm randomly or collectively, we find that collectively behaving bugs tend to align, which results in relatively more cohesive groups. In addition, cohesion among bats is induced since bats may be attracted to the same localized bug group. Due to the fact that bats need to hunt more widely for groups of bugs, collectively behaving bugs suffer less predation compared to their randomly swarming counterparts. These findings are supported by the biological literature which cites protection from predation as a primary motivator for social behavior.

10:55-11:15	WeAT5.3

Determining Human Control Intent Using Inverse LQR Solutions (I), pp. 1887-1894

Priess, M. Cody	Michigan State Univ.
Choi, Jongeun	Michigan State Univ.
Radcliffe, Clark J.	Michigan State Univ.

In this paper, we have developed a method for determining the control intention in human subjects during a prescribed motion task. Our method is based on the solution to the inverse LQR problem, which can be stated as: does a given controller K describe the solution to a time-invariant LQR problem, and if so, what weights Q and R produce K as the optimal solution? We describe an efficient Linear Matrix Inequality (LMI) method for determining a solution to the general case of this inverse LQR problem when both the weighting matrices Q and R are unknown. Additionally, we propose a gradient-based, least-squares minimization method that can be applied to approximate a solution in cases when the LMIs are infeasible. We develop a model for an upright seated-balance task which will be suitable for identification of human control intent once experimental data is available.

11:15-11:35	WeAT5.4

Bio-Inspired Nonholonomic Tracking Control (I), pp. 1895-1904

Shoemaker, Adam	Virginia Tech.
Leonessa, Alexander	Virginia Tech.

The behavior of nature's predators is considered for designing a high speed tracking controller for nonholonomic vehicles, whose dynamics are represented using a unicycle model. To ensure that the vehicle behavior closely resembles that of a predator, saturation constraints are added and accounted for using Lyapunov stability criterion. Following verification and comparison of the saturation constraints, the proposed algorithm is implemented on a testing platform. Based on the results presented, we believe the algorithm shows significant promise in high speed control and obstacle avoidance.

11:35-11:55	WeAT5.5

A Predictor-Compensator Design to Assist Human Decision-Making Process in an Air-Traffic-Control Simulator (I), pp. 1905-1913

Sadeghzadeh, Keivan | Northeastern Univ.
Sipahi, Rifat | Northeastern Univ.

Air traffic control is a demanding task for human operators, as this task requires tracking multiple events, managing the events, and taking actions in the presence of multiple and possibly competing objectives. In such critical tasks, human intelligence is extremely crucial however human decisions also become more prone to errors, which could cause tragic events. One idea to prevent such errors is to design smart machines that can assist human subjects in making decisions whenever human errors become more likely. In this article, we present a simulation model that captures the essence of how a human subject model would interact with a simplified version of an air traffic control simulator, and show how we design a predictor-compensator in order to regulate and possibly improve this interaction, such that overall human-machine interface can be optimized, and human workload is reduced on average.

11:55-12:15 WeAT5.6

Timoshenko Beam Model for Exploration and Sensing with a Continuum Centipede Inspired Robot (I), pp. 1914-1921

Fattahi, S.Javad | Univ. of Ottawa
Spinello, Davide | Univ. of Ottawa

We present the continuum model of a robot inspired by organisms like centipedes and polychaete worms. The continuum model is obtained as the limit of a rigid body chain with pinned elements, which leads to a Timoshenko beam model that is described by a one dimensional continuum with local Euclideian structure. The local Euclideian structure models the cross sections that are kinematically described by their position and orientation. The leg structures in the biological systems are modeled in the continuum limit as a distribution of compliant elements. Modal properties of the system are investigated. The compliance of the legs can be exploited for sensing purposes with specific application to the reconstruction of the surrounding environment and to the estimation of physical properties. The class of models in this papers applies to the continuum description of several emerging robotic application that range from tools for exploration in hazardous or generally not accessible environments (to humans) to novel healthcare systems as for example endoscopic tools for diagnostic in the gastrointestinal tract.

WeAT6 Room 134

Beams and Flexible Structures (Contributed session)

Chair: Chalhoub, Nabil | Wayne State Univ.
Co-Chair: Jalili, Nader | Northeastern Univ.

10:15-10:35 WeAT6.1

Effects of Non-Collocated Sensors and Actuators on the Controller of a Flexible Beam, pp. 1922-1928

Mastory, Constantine | Wayne State Univ.
Chalhoub, Nabil | Wayne State Univ.

The current work examines the adverse effects of non-collocated sensors and actuators on the phase characteristics of flexible structures. The sensor location is allowed to sweep the entire length of a pinned-free flexible beam while the actuator is fixed at the pinned-end. The phase angle contour of the system has been generated as a function of the normalized sensor location and the excitation frequency. It clearly reveals the minimum and non-minimum phase regions of the system and illustrates the changes in the system's zeros induced by varying the sensor location. A basic sliding mode controller has been used to attenuate the unwanted vibrations of the beam. Based on the phase angle contours of the system, the structural controller has been modified to ensure a desirable controller performance irrespective of the sensor location with respect to the actuator. The simulation results demonstrate the efficacy of the modified controller in attenuating the overall transverse deformation of the beam irrespective of its phase characteristic.

10:35-10:55 WeAT6.2

Ultra Sensitive Piezoelectric-Based Microcantilever Sensor Operating at High Modes for Detection of Ultrasmall Masses, pp. 1929-1938

Faegh, Samira | Northeastern Univ.
Jalili, Nader | Northeastern Univ.

Detection of ultrasmall masses such as proteins and pathogens has been made possible as a result of nano-technological advancements. Development of label-free and highly sensitive biosensors has enabled the transduction of molecular recognition into detectable physical quantities. MicroCantilever (MC)-based systems have played a widespread role in developing such biosensors. One of the most important drawbacks of the available biosensors their high cost. Moreover, biosensors are normally quipped with external devices such as actuator and read out systems which are bulky and expensive. A unique self-sensing detection technique is proposed in this paper in order to address the limitations of the measurement systems. A number of approaches have been reported for enhancing the sensitivity of MC-based systems including geometry modification, employing nanoparticle-enhanced MCs and operating MCs in lateral and torsional modes. Although being investigated, there have not been analytical high fidelity models describing comprehensive dynamics and behavior of MCs operating in high modes. In this study, a comprehensive mathematical modeling is presented for the proposed self-sensing detection platform operating at ultrahigh mode using distributed-parameters system modeling. Mode convergence theory was adopted to have an accurate level of estimation. An extensive experimental setup was built using piezoelectric MC operating at high mode which verified theoretical modeling results. Finally, the whole platform was utilized as a biosensor for detection of ultrasmall adsorbed mass along with the theoretical and experimental results and verification. It was proved that operating MC at ultrahigh mode increases the sensitivity of system to detect adsorbed mass as a result of increased quality factor.

10:55-11:15 WeAT6.3

Derivatives and Parameter Designs of Arbitrary Cross-Section Inhomogenous Beams' Modes, pp. 1939-1945

Xing, Jianwei | Tsinghua Univ.
Zheng, Gangtie | Tsinghua Univ.

As highly sensitive to structural parameter variations, it is necessary to study relations between derivatives of displacement modes and structural design parameters. This paper proposes an integral technique for obtaining the analytical solutions of slope and curvature modes of arbitrary cross-section inhomogeneous cantilever beam. The method is validated by comparing the computation results of modal frequencies and shapes with both numerical and analytical solutions. Furthermore, based on the presented method, we have established explicit expressions for the structural parameters sensitivity of the slope/curvature mode shapes. An example of parameter design is also presented for a cantilever beam with the proposed sensitivity analysis method.

11:15-11:35 WeAT6.4

Free Vibration Analysis of a Beam with an Attached In-Span Beam with Tip Mass, pp. 1946-1953

Oumar, Barry | Univ. of Toronto
Oguamanam, Donatus | Ryerson Univ.
Zu, Jean | Univ. of Toronto

A double-beam system is used to model a single conductor transmission line with a Stockbridge damper. The base beam represents the conductor and is subjected to an axial tensile load. The in-span beam with a tip mass at each end models the Stockbridge damper and it is arbitrarily attached to the base beam. Using Hamilton's principle, the system equations of motion are derived and an expression is presented for the frequency equation. The formulation is validated with finite element results in the literature. Parametric studies are done to investigate the influence of the flexural rigidity and location of the in-span beam on the lowest five natural frequencies of the system. Investigation is also performed to examine the effect of the distance separating to two beams.

11:35-11:55	WeAT6.5

Modeling and Control of a Thermoelastic Beam, pp. 1954-1959

Tuzcu, Ilhan — California State Univ. Sacramento
Gonzalez-Rocha, Javier — California State Univ. Sacramento

The objective of this paper is to model a thermoelastic beam and use thermoelectric heat actuators dispersed over the beam to control not only its vibration, but also its temperature. The model is represented by two coupled partial differential equations governing the elastic bending displacement and temperature variation over the length of the beam. The partial differential equations are replaced by a set of ordinary differential equations through discretization. The first-order ordinary differential equations are cast in the compact state-space form to be used in the thermoelastic analysis and control. The Linear Quadratic Gaussian (LQG) is used for control design. An numerical application to a uniform cantilever beam demonstrates the coupling between the temperature and the elastic displacement and feasibility of using thermoelectric actuators in controlling the vibration and temperature simultaneously.

11:55-12:15	WeAT6.6

Diagnostic Subspace Identification for the Dynamical Structural Models (I), pp. 1960-1967

Almutawa, Jaafar — King Fahd Univ. of Petroleum and Minerals

Recently more attention has been given to the application of the so called subspace system identification methods to the dynamical structural models. In fact, the dynamical structural models can be written in the form of stochastic state space model. This paper propose several diagnostic techniques for the state space model fitting in the subspace system identification algorithms framework by deleting observations from the data and measuring the change in the estimates of the parameters. This method is considered for measuring the influential subsets in the state space model. We generalize the Welsch statistics in order to be applicable to the state space model to measure the effect of adding more variables to the model. Furthermore, a new algorithm to detect the outliers (damage detection and health monitoring) for the structural model has been developed. Moreover, we propose a Cook's distance to identify the influential outlying cases. It also shown that the diagnostics based on the innovations variance are much clearer and more sensitive than those for the coefficients. A Monte Carlo simulation of the vibrating structure model demonstrated the effectiveness of the proposed algorithms and there ability to check the validity of the model, detect outliers.

WeAT7 — Room 138

Linear Systems and Robust Control (Contributed session)

Chair: Nersesov, Sergey G. — Villanova Univ.
Co-Chair: Duan, Chang — North Carolina State Univ.

10:15-10:35	WeAT7.1

New Results on Continuous-Time Switched Linear Systems with Actuator Saturation, pp. 1968-1976

Duan, Chang — North Carolina State Univ.
Wu, Fen — North Carolina State Univ.

This paper further studies the analysis and control problem of continuous-time switched linear systems subject to actuator saturation. Using the norm-bounded differential inclusion (NDI) characterization of the saturated systems and the minimal switching rule, a set of switched output feedback controllers is designed to minimize disturbance attenuation level defined by the regional L2 gain over a class of energy-bounded disturbances. The synthesis conditions are expressed as bilinear matrix inequalities (BMIs) and can be solved by numerical search coupled with linear matrix inequalities (LMIs) optimization. Compared to the previous method based on polytopic differential inclusion (PDI), the proposed approach has good scalability and potentially achieve better performance. Numerical examples are provided to show the effectiveness of the proposed approach.

10:35-10:55	WeAT7.2

A Linear Matrix Inequality Solution to the Input Covariance Constraint Control Problem, pp. 1977-1983

White, Andrew — Michigan State Univ.
Zhu, Guoming — Michigan State Univ.
Choi, Jongeun — Michigan State Univ.

In this paper, the input covariance constraint (ICC) control problem is solved by a convex optimization with linear matrix inequality (LMI) constraints. The ICC control problem is an optimal control problem that is concerned with finding the best output performance possible subject to multiple constraints on the input covariance matrices. The contribution of this paper is the characterization of the control synthesis LMIs used to solve the ICC control problem. To demonstrate the effectiveness of the proposed approach a numerical example is solved with the control synthesis LMIs. Both discrete and continuous-time problems are considered.

10:55-11:15	WeAT7.3

Robust Control of Switched Linear Systems Via Min of Quadratics, pp. 1984-1993

Yuan, Chengzhi — North Carolina State Univ.
Wu, Fen — North Carolina State Univ.

In this paper, we investigate the robust switching control problem for switched linear systems by using a class composite quadratic function, the min (of quadratics) function, to improve performance and enhance control design flexibility. The robustness is reflected in two prospectives including the $mathcal{H}_{infty}$ performance and arbitrary switching of subsystems. A hysteresis min-switching strategy will be employed to orchestrate the switching among a collection of controllers. The synthesis conditions for both state feedback and output feedback control problems are derived in terms of a set of linear matrix inequalities (LMIs) with linear search over scalar variables. The proposed min function based approach combines the existing single Lyapunov function based method and multiple Lyapunov function based method into a general framework, and the derived LMI conditions cover the existing LMI conditions as special cases. Numerical studies are included to demonstrate the advantages of the proposed control design approach.

11:15-11:35	WeAT7.4

Output Reversibility in Linear Discrete-Time Dynamical Systems, pp. 1994-2001

Nersesov, Sergey G. — Villanova Univ.
Deshmukh, Venkatesh — Villanova Univ.
Ghasemi, Masood — Villanova Univ.

Output reversibility involves dynamical systems where for every initial condition and the corresponding output there exists another initial condition such that the output generated by this initial condition is a time-reversed image of the original output with the time running forward. Through a series of necessary and sufficient conditions, we characterize output reversibility in linear single-output discrete-time dynamical systems in terms of the geometric symmetry of its eigenvalue set with respect to the unit circle in the complex plane. Furthermore, we establish that output reversibility of a linear continuous-time system implies output reversibility of its discretization regardless of the sampling rate. Finally, we present a numerical example involving a discretization of a Hamiltonian system that exhibits output reversibility.

11:35-11:55	WeAT7.5

Asymptotic Properties of Zeros of Sampled-Data Systems for Continuous-Time Plants with Nondecouplability, pp. 2002-2006

Ishitobi, Mitsuaki — Kumamoto Univ.
Kunimatsu, Sadaaki — Osaka Univ.

When a continuous-time linear system is discretized using a hold, stability of poles are preserved. However, the transformations of zeros are much more complicated and the number of the zeros incresases in some cases in the discretization process. This paper is concerned with the zeros of a sampled-data model resulting from a continuous-time multivariable system which is not decouplable by static state feedback and has all of the relative degrees one. Two cases of a zero-order hold and a fractional-order hold are treated. An approximate expression of the zeros is given as power series expansions with respect to a sampling period in the zero-order hold case. Further, the limiting zeros are analyzed in the fractional-order hold case. Then, the advantage of the fractional-order hold to the zero-order hold is discussed from the viewpoint of stability of the zeros.

11:55-12:15 — WeAT7.6

A High Performance Tracking Control Method Based on a Disturbance Observer with Parameter Adaptation, pp. 2007-2015

Hyun, Dong Jin — Massachusetts Inst. of Tech.
Choi, Jungsu — Sogang Univ.
Kong, Kyoungchul — Sogang Univ.

A disturbance observer (DOB) is a useful control algorithm for systems with uncertain dynamics, such as nonlinearity and time-varying dynamics. The DOB, however, is designed based on a nominal model, and its stability is sensitive to the magnitude of discrepancy between a controlled system and its nominal model. Therefore, to increase the stability margin of the DOB, it requires an accurate model identification, which is often difficult for nonlinear or uncertain systems. In this paper, the parameters of the nominal model are continuously updated by a parameter adaptation algorithm (PAA) to keep the model discrepancy small, such that the DOB is able to show its desired performance without losing stability robustness even in the presence of nonlinearity and/or time-varying dynamics. In the integration of the DOB and the PAA, however, there exists a complicated signal interaction. In this paper, such interaction problem is solved from a practical point of view; signal filtering. The proposed method shows improved performance for an electric motor system, and is verified by experimental results in this paper.

WeBT1 — Paul Brest East

Vehicle Path Planning and Collision Avoidance (Invited session)

Chair: Sadrpour, Amir — Univ. of Michigan
Co-Chair: Kolodziej, Jason — Rochester Inst. of Tech.
Organizer: Scacchioli, Annalisa — New York Univ.
Organizer: Kolodziej, Jason — Rochester Inst. of Tech.
Organizer: Canova, Marcello — The Ohio State Univ.
Organizer: Shahbakhti, Mahdi — Michigan Tech. Univ.
Organizer: Hall, Carrie — Purdue Univ.
Organizer: Yan, Fengjun — McMaster Univ.

13:30-13:50 — WeBT1.1

Guidance of a Robotic Off-Road Tractor-Trailer System Using Model Predictive Control (I), pp. 2016-2021

Salmon, James — Auburn Univ.
Bevly, David — Auburn Univ.
Hung, John Y. — Auburn Univ.

This paper presents a nonlinear Model Predictive Control approach to controlling a tractor-trailer system. Using a non-linear tractor-trailer model, the controller determines the optimal steer angle, based on the trailer's measured position and heading, as well as information about the path geometry in front of it. Then, the computer determines the amount of voltage to apply to the steering wheel motor to achieve the necessary steer angle. In the simulation study, the controller algorithm is capable of guiding a 2-1/2 meter long trailer around a 5-meter radius turn, towed by a four wheel drive off-road utility vehicle, with a maximum error of 8.5 centimeters.

13:50-14:10 — WeBT1.2

Real-Time Energy-Efficient Path Planning for Unmanned Ground Vehicles Using Mission Prior Knowledge (I), pp. 2022-2031

Sadrpour, Amir — Univ. of Michigan
Ulsoy, A. Galip — Univ. of Michigan
Jin, Judy — Univ. of Michigan

Surveillance missions that involve unmanned ground vehicles (UGVs) include situations where a UGV has to choose between alternative paths to complete its mission. Currently, UGV missions are often limited by the available on-board energy. Thus, we propose a dynamic most energy-efficient path planning algorithm that integrates mission prior knowledge with real-time sensory information to identify the mission's most energy-efficient path. Our proposed approach predicts and updates the distribution of energy requirement of alternative paths using recursive Bayesian estimation through two stages: (1) exploration - road segments are explored to reduce their energy prediction uncertainty; (2) exploitation - the most energy-efficient path is selected using the collected information in the exploration stage and is traversed. Our simulation results show that the proposed approach outperforms offline methods, as well as a method that only relies on exploitation to identify the most energy-efficient path.

14:10-14:30 — WeBT1.3

Simple Clothoid Paths for Autonomous Vehicle Lane Changes at the Limits of Handling (I), pp. 2032-2041

Funke, Joseph — Stanford Univ.
Gerdes, J. Christian — Stanford Univ.

This paper demonstrates that an autonomous vehicle can perform emergency lane changes up to the limits of handling through real-time generation and evaluation of bi-elementary paths. Path curvature and friction limits determine the maximum possible speed along the path and, consequently, the feasibility of the path. This approach incorporates both steering inputs and changes in speed during the maneuver. As a result, varying path parameters and observing the maximum possible entry speed of resulting paths gives insight about when and to what extent a vehicle should brake and turn during emergency lane change maneuvers. Tests on an autonomous vehicle validate this approach for lane changes at the limits of handling.

14:30-14:50 — WeBT1.4

Multi-Objective Collision Avoidance (I), pp. 2042-2051

Ali, Mohammad — Volvo Car Corp.
Gray, Andrew — Univ. of California Berkeley
Gao, Yiqi — Univ. of California, Berkeley
Hedrick, Karl — Univ. of California at Berkeley
Borrelli, Francesco — UC Berkeley

This paper presents a multi-objective safety system that is capable of avoiding unintended collisions with stationary and moving road obstacles, vehicle control loss as well as unintended roadway departures. The safety system intervenes only when there is an imminent safety risk while full control is left to the driver otherwise. The problems of assessing wether an intervention is required as well as controlling the vehicle motion in case an intervention is needed are jointly formulated as a single optimization problem, that is repeatedly solved in receding horizon. The novelty of the formulation lies in the ability of simultaneously avoiding moving obstacles while assessing the necessity thereof. The versatility of the proposed formulation is demonstrated through simulations showing its ability of avoiding a wide range of accident scenarios.

14:50-15:10 — WeBT1.5

Determination of Minimum State Preview Time to Prevent Vehicle

Rollover (I), pp. 2052-2059

Stankiewicz, Paul	Penn State Univ.
Brown, Alexander	The Pennsylvania State Univ.
Brennan, Sean	Penn State Univ.

This research focuses on determining the minimum preview time needed to predict and prevent vehicle rollover. Statistics show that although rollover only occurs in 2.2% of total highway crashes, it accounts for 10.7% of total fatalities. There are several dynamic rollover metrics in use that measure a vehicle's rollover propensity under specified conditions. However, in order to prevent a rollover event from occurring, it is necessary to predict a vehicle's future rollover propensity. This research uses a novel vehicle rollover metric, called the zero-moment point (ZMP), to predict a vehicle's rollover propensity. Comparing different amounts of preview, the results show that short-range predictions - as little as 0.75 seconds ahead of the vehicle - are sufficient to prevent nearly all dynamics-induced rollovers in typical shoulders and medians.

15:10-15:30 WeBT1.6

Using a Path-Fitting Algorithm to Analyze the Racing Techniques of a Skilled Driver (I), pp. 2060-2066

Samper-Mejia, Juan-Pablo	Stanford Univ.
Theodosis, Paul A.	Stanford Univ.
Gerdes, J. Christian	Stanford Univ.

Racecar drivers are skilled at tracking a path, avoiding accidents, and controlling their vehicles at the limits of handling. Better understanding of how a skilled driver selects and drives a racing line, could potentially lead to a new technique for obstacle avoidance. To investigate this, the characteristics of a racecar driver's line must be captured mathematically. This paper describes an algorithm for fitting a path to the GPS data of a driver's racing line. A family of path primitives composed of straights, clothoids, and constant radius arcs are used to describe the racing line. The fitted paths provide a method for analyzing racing lines and the different techniques used by skilled drivers to navigate the track.

WeBT2 Room 123

Robotics and Manipulators (Contributed session)

Chair: Chen, Wenjie	Univ. of California at Berkeley
Co-Chair: Lee, Kok-Meng	Georgia Inst. of Tech.

13:30-13:50 WeBT2.1

Automatic Sensor Frame Identification in Industrial Robots with Joint Elasticity, pp. 2067-2075

Lin, Chung-Yen	Univ. of California, Berkeley
Chen, Wenjie	Univ. of California at Berkeley
Tomizuka, Masayoshi	Univ. of California, Berkeley

For robots with joint elasticity, discrepancies exist between the motor side information and the load side (i.e., end-effector) information. Therefore, high tracking performance at the load side can hardly be achieved when the estimate of load side information is inaccurate. To minimize such inaccuracies, it is desired to calibrate the load side sensor (in particular, the exact sensor location). In practice, the optimal placement of the load side sensor often varies due to the task variation necessitating frequent sensor calibrations. This frequent calibration need requires significant effort and hence is not preferable for industries which have relatively short product cycles. To solve this problem, this paper presents a sensor frame identification algorithm to automate this calibration process for the load side sensor, in particular the accelerometer. We formulate the calibration problem as a nonlinear estimation problem with unknown parameters. The Expectation-Maximization algorithm is utilized to decouple the state estimation and the parameter estimation into two separated optimization problems. An overall dual-phase learning structure associated with the proposed approach is also studied. Experiments are designed to validate the effectiveness of the proposed algorithm.

13:50-14:10 WeBT2.2

Impedance Reduction Controller Design for Mechanical Systems, pp. 2076-2081

Woo, Hanseung	Sogang Univ.
Kong, Kyoungchul	Sogang Univ.

Safety is one of important factors in control of mechatronic systems interacting with humans. In order to evaluate the safety of such systems, mechanical impedance is often utilized as it indicates the magnitude of reaction forces when the systems are subjected to motions. Namely, the mechatronic systems should have low mechanical impedance for improved safety. In this paper, a methodology to design controllers for reduction of mechanical impedance is proposed. For the proposed controller design, the mathematical definition of the mechanical impedance for open-loop and closed-loop systems is introduced. Then the controllers are designed for stable and unstable systems such that they effectively lower the magnitude of mechanical impedance with guaranteed stability. The proposed method is verified through case studies including simulations.

14:10-14:30 WeBT2.3

Fast Modeling and Identification of Robot Dynamics Using the Lasso, pp. 2082-2085

Wang, Cong	Univ. of California, Berkeley
Yu, Xiaowen	UC berkeley
Tomizuka, Masayoshi	Univ. of California, Berkeley

This paper presents an approach for fast modeling and identification of robot dynamics. By using a data-driven machine learning approach, the process is simplified considerably from the conventional analytical method. Regressor selection using the Lasso (l1-norm penalized least squares regression) is used. The method is explained with a simple example of a two-link direct-drive robot. Further demonstration is given by applying the method to a three-link belt-driven robot. Promising result has been demonstrated.

14:30-14:50 WeBT2.4

A Random Matrix Approach to Manipulator Jacobian, pp. 2086-2095

Sovizi, Javad	Univ. at Buffalo
Alamdari, Aliakbar	Univ. at Buffalo
Krovi, Venkat N.	SUNY Buffalo

Traditional kinematic analysis of manipulators, built upon a deterministic articulated kinematic modeling often proves inadequate to capture uncertainties affecting the performance of the real robotic systems. While a probabilistic framework is necessary to characterize the system response variability, the random variable/vector based approaches are unable to effectively and efficiently characterize the system response uncertainties. Hence in this paper, we propose a random matrix formulation for the Jacobian matrix of a robotic system. It facilitates characterization of the uncertainty model using limited system information in addition to taking into account the structural inter-dependencies and kinematic complexity of the manipulator. The random Jacobian matrix is modeled such that it adopts a symmetric positive definite random perturbation matrix. The maximum entropy principle permits characterization of this perturbation matrix in the form of a Wishart distribution with specific parameters. Comparing to the random variable/vector based schemes, the benefits now include: incorporating the kinematic configuration and complexity in the probabilistic formulation, achieving the uncertainty model using limited system information (mean and dispersion parameter), and realizing a faster simulation process. A case study of a 6R serial manipulator (PUMA 560) is presented to highlight the critical aspects of the process. A Monte Carlo analysis is performed to capture the deviations of distal path from the desired trajectory and the statistical analysis on the realizations of the end effector position and orientation shows how the uncertainty propagates throughout the system.

14:50-15:10 WeBT2.5

Dynamics Modeling and Identification of a Dual-Blade Wafer Handling Robot, pp. 2096-2102

Yu, Xiaowen	UC berkeley
Wang, Cong	Univ. of California, Berkeley
Zhao, Yu	Tsinghua Univ.
Tomizuka, Masayoshi	Univ. of California, Berkeley

This paper presents the dynamics modeling and dynamic identification of a dual-blade wafer handling robot. An explicit form dynamic model for this 8-link parallel robot is proposed. The dynamic model is transformed into a decoupled form to enable dynamic parameters identification with least-square regression. A well conditioned trajectory is chosen for identification experiment. Both viscous friction and Coulomb friction are considered to make the model more reliable. Model has been validated by experiments.

15:10-15:30 WeBT2.6

Discrete Deformation Models for Real-Time Computation of Compliant Mechanisms, pp. 2103-2111

Ji, Jingjing	Zhejiang Univ.
Lee, Kok-Meng	Georgia Inst. of Tech.

This paper presents the formulation of a reduced-order linear discrete–path approximation in state space and its solution as a function of path lengths for a 3D curvature-based beam model (CBM). Solutions to both forward and inverse problems are discussed; the former is essential for real-time deformed shape visualization whereas the latter is much needed for haptic force feedback. The method is illustrated with an application example where a 2D beam is characterized by a 6th order CBM. Practical implementation shows that when external forces as system input are expressed in global coordinates, the CBM can be decoupled into two 2nd order systems enabling parallel computing of the deformed shape and the orientation and moment, and effectively reducing the table size for storing the operating conditions. The proposed real-time computation method has been validated by verifying results against published experimental and MSM simulated data.

WeBT3 Tent A

Sensing (Contributed session)

Chair: Kim, Won-jong	Texas A&M Univ.
Co-Chair: Clayton, Garrett	Villanova Univ.

13:30-13:50 WeBT3.1

Spatial Feature Matching for Visual Odometry: A Parametric Study, pp. 2112-2118

Clayton, Garrett	Villanova Univ.
Fabian, Joshua	Villanova Univ.

The goal of this paper is to perform a parametric study on a newly developed visual odometry algorithm for use with color-depth (RGB-D) camera pairs, such as the Microsoft Kinect. In this algorithm, features are detected in the color image and converted to 3D points using the depth image. These features are then described by their 3D location and matched across subsequent frames based on spatial proximity. The visual odometry is then calculated using a one-point inverse kinematic solution. The primary contribution of this work is the identification of critical operating parameters associated with the algorithm, the analysis of their effects on the visual odometry performance, and the verification of the analysis using experimentation.

13:50-14:10 WeBT3.2

Visual Servoing for Robot Manipulators Considering Sensing and Dynamics Limitations, pp. 2119-2126

Wang, Cong	Univ. of California, Berkeley
Lin, Chung-Yen	Univ. of California, Berkeley
Tomizuka, Masayoshi	Univ. of California, Berkeley

This paper presents a control scheme of visual servoing. Real-time vision guidance is necessary in many desirable applications of industrial manipulators. Challenge comes from the limitations of visual sensing and robot dynamics. Typical industrial machine vision systems have low sampling rate and large latency. In addition, due to the large inertia of industrial manipulators, a proper consideration of robot dynamics is important. In particular, actuator saturation may cause undesirable response. In this paper, an adaptive tracking filter is used for sensing compensation. Based on the compensated vision feedback, a two-layer controller is formulated using multi-surface sliding control. System kinematics and dynamics are decoupled and handled by the two layers of the controller respectively. Further, a constrained optimal control approach is adopted to avoid actuator saturation. Validation is conducted using a SCARA robot.

14:10-14:30 WeBT3.3

Vibration Measurement and Monitoring of a Rotating Disk Using Contactless Laser Excitation (I), pp. 2127-2131

Kajiwara, Itsuro	Hokkaido Univ.
Hosoya, Naoki	Shibaura Inst. of Tech.

It is critical to monitor the behavior and characteristics of a machinery, running under extreme conditions of high speed and high temperature (e.g., a jet engine or turbines used in power plants), to ensure safety of its operation. In addition, it is important to measure/evaluate the vibration characteristics of the spinning disk against various excitation forces, including the motor-driven transmission power and fluid power, to improve the accuracy of precision machinery rotating at a high speed, such as the hard disk drive (HDD). This paper proposes a contactless vibration testing system for rotating disks based on an impulse response excited by a laser ablation. The laser excitation technology, which induces an excitation force in a contactless manner and inputs ideal impulse waveforms, is capable of accurately measuring the vibration characteristics of a system operating at high frequency. In addition, the laser excitation has high reproducibility of the acting excitation force, therefore it is possible to improve the reliability of the measurements. The contactless vibration testing system is composed of a YAG pulse laser, laser Doppler vibrometer and spectrum analyzer. This system makes it possible to measure vibration characteristics of structures under operation, such as vibration measurement of a rotating disk. The effectiveness of this system is confirmed by experimental and theoretical analyses. In this paper, a platter of hard disk drive is employed as an experimental object. Vibration characteristics of a rotating and non-rotating platter are measured and compared with the results of theoretical analysis.

14:30-14:50 WeBT3.4

Robust State Estimation with Redundant Proprioceptive Sensors, pp. 2132-2141

Rollinson, David	Carnegie Mellon Univ.
Choset, Howie	Carnegie Mellon Univ.
Tully, Stephen	Carnegie Mellon Univ.

We present a framework for robust estimation of the config- uration of an articulated robot using a large number of redundant proprioceptive sensors (encoders, gyros, accelerometers) distributed throughout the robot. Our method uses an Unscented Kalman Filter (UKF) to fuse the robot's sensor measurements. The filter estimates the angle of each joint of the robot, enabling the accurate estimation of the robot's kinematics even if not all modules report sensor readings. Additionally, a novel outlier detection method allows the the filter to be robust to corrupted accelerometer and gyro data.

14:50-15:10 WeBT3.5

A Human Motion Capture System Based on Inertial Sensing and a Complementary Filter, pp. 2142-2150

Kanjanapas, Kan	Univ. of California at Berkeley
Wang, Yizhou	Univ. of California at Berkeley
Zhang, Wenlong	Univ. of California at Berkeley
Whittingham, Lauren	UC Berkeley

Tomizuka, Masayoshi | Univ. of California, Berkeley

A human motion capture system is becoming one of the most useful tools in rehabilitation application because it can record and reconstruct a patient's motion accurately for motion analysis. In this paper, a human motion capture system is proposed based on inertial sensing. A microprocessor is implemented on-board to obtain raw sensing data from the inertial measurement unit (IMU), and transmit the raw data to the central processing unit. To reject noise in the accelerometer, drift in the gyroscope, and magnetic distortion in the magnetometer, a time varying complementary filter (TVCF) is implemented in the central processing unit to provide accurate attitude estimation. A forward kinematic model of the human arm is developed to create an animation for patients and physical therapists. Performance of the hardware and filtering algorithm is verified by experimental results.

15:10-15:30 WeBT3.6

A New Rotary Position-Control System with Color Sensing, pp. 2151-2159

Kwon, Young-shin | Texas A&M Univ.
Kim, Won-jong | Texas A&M Univ.

This paper presents a new rotary position-control system using a color sensor. The angle sensing mechanism is based on the working principle of a red-green-blue (RGB) sensor that measures the radiant-intensity variation of the light reflected on the color surface. The optical-power propagation mechanism from a light-emitting diode (LED) source to the RGB sensor's voltage is investigated using the light reflected on the designated-RGB codes of the cylindrical color-track surface. The nonlinearity due to a color printer and a paper roughness is compensated for through iterative comparisons with the reference angle achieved from a precision potentiometer. The performance of this new absolute angle sensor is validated using a rotary mechanical system with a cylindrical inertia controlled by a lead compensator. The stability of the positioning system is also investigated with the frequency response. Eventually, the feasibility of this new rotary angle sensor with the cost-effective and non-contact sensing mechanism is demonstrated.

WeBT4 Paul Brest West

Control of Mechanical Systems (Contributed session)

Chair: Richer, Edmond | Southern Methodist Univ.
Co-Chair: Pagilla, Prabhakar R. | Oklahoma State Univ.

13:30-13:50 WeBT4.1

Modeling, Identification and Adaptive Robust Motion Control of Voice-Coil Motor Driven Stages, pp. 2160-2167

Li, Chao | Zhejiang Univ.
Chen, Zheng | Dalhousie Univ.
Yao, Bin | Zhejiang Univ.
Wang, Qingfeng | Zhejiang Univ.

13:50-14:10 WeBT4.2

Hardening and Softening Characteristics of a Piecewise Linear Isolator under 1g Gravity, pp. 2168-2174

Wang, Xing | Tsinghua Univ.
Zheng, Gangtie | Tsinghua Univ.

The frequency responses of a piecewise isolator mounted on a moving flexible base are investigated. A procedure, which is based on Equivalent Linearization method and transfer function, is proposed to study this two-degrees-of freedom nonlinear system. The influence of 1G gravity on the nonlinearity of the system frequency responses is investigated and presented in detail. It is shown that the piecewise stiffness may demonstrate both hardening and softening properties due to different amplitude, clearance and gravity.

14:10-14:30 WeBT4.3

Decentralized Control of Print Registration in Roll-To-Roll Printing Presses, pp. 2175-2184

Seshadri, Aravind | Oklahoma State Univ.
Pagilla, Prabhakar R. | Oklahoma State Univ.

Roll-to-roll (R2R) manufacturing is a type of continuous manufacturing process extensively used to produce a wide variety of consumer products, such as plastics, paper, films, nonwovens, textile, etc. Recent advances in nanotechnology and material science have enabled the possibility of manufacturing electronics on a flexible substrate using R2R printing techniques. Even though the feasibility of printing electronics on flexible substrates has been extensively studied, continuous printing on a moving substrate using R2R techniques has not been adequately investigated. To facilitate progress towards high precision R2R printing, a systematic investigation of the various aspects that affect print quality and ways in which those can be influenced by different control configurations facilitated by choice and location of various components of the print section is necessary.

In this paper we investigate two common control configurations for R2R printing based on the structure of the R2R print section and various components available for control. For these two configurations we develop a state-space model that contains both state and input delays. We propose a decentralized, memoryless, state feedback control law for both control configurations and show the stability of the closed loop systems using frequency domain delay-dependent stability conditions. These control configurations are evaluated and compared using model simulations and discussions on the effectiveness of each strategy are provided.

14:30-14:50 WeBT4.4

Development of Energy Management Strategies for Heavy Mobile Machinery, pp. 2185-2192

Lajunen, Antti | Aalto Univ.

This paper introduces a method for developing energy management strategies (EMS) for task-oriented heavy mobile machinery. The case application is a hybrid underground mining loader but the method is also used for a diesel-electric and electric loader. Depending on the optimization target, the sequence for optimal power-split between the engine-generator (gen-set) and battery is defined. The minimization of the energy consumption and maximization of the operating efficiency are used as the optimization targets. The developed method is based on dynamic programming simulations which generate the optimal power-split for the evaluation of the control parameters. The simulation results showed that there are no significant differences between the two optimization targets in terms of the control sequence of the hybrid loader. The major difference was observed in the battery charging power which was much lower in the case of the minimization of the energy consumption.

14:50-15:10 WeBT4.5

A Validated System-Level Thermodynamic Model of a Reciprocating Compressor with Application to Valve Condition Monitoring, pp. 2193-2202

Kolodziej, Jason | Rochester Inst. of Tech.
Guerra, Christopher | Dresser-Rand

Condition-based health monitoring systems are a very important addition to machinery to monitor the system and assure it is running at the peak efficiency, to schedule maintenance, and prevent catastrophic failure. Recently, these systems have started to become more common on industrial compression technology. Reciprocating compressor health monitoring systems typically use only indirect measurements, P-V diagrams, to monitor the health of the system.

Specifically this research focuses on three different valve failure modes that are common in reciprocating compressors. They are liquid slugging, valve spring fatigue, and valve seat wear. First a system-level model of a Dresser-Rand industrial reciprocating compressor is derived and validated, experimentally, to better understand how different subsystem dynamics are related through the compressor. Also, a preliminary instrument investigation is conducted to determine what sensor types are the most effective at detecting these faults.

15:10-15:30	WeBT4.6

A Lumped-Parameter Model for Dynamic MR Damper Control, pp. 2203-2207

Case, David	Southern Methodist Univ.
Taheri, Behzad	Southern Methodist Univ.
Richer, Edmond	Southern Methodist Univ.

The dynamic behavior of a small-scale magnetorheological damper intended for use in a tremor-suppression orthosis is characterized through experimental analysis and finite element simulation. The combined frequency response of both the electromagnetic coil and the fluid particles is modeled by a second-order transfer function. The output of this function is an effective current that, combined with piston velocity, is empirically related to resistance force of the damper. The derived model demonstrates high-fidelity to experimental testing of the damper under variable piston velocity and applied current within the expected frequency range of pathological tremor. The model is thus deemed suitable for use in a control algorithm for the mechanical suppression of tremor.

WeBT5	Tent B

System Identification and Modeling (Invited session)

Chair: Kfoury, Giscard	Lawrence Tech. Univ.
Co-Chair: Chalhoub, Nabil	Wayne State Univ.
Organizer: Kfoury, Giscard	Lawrence Tech. Univ.
Organizer: Chalhoub, Nabil	Wayne State Univ.

13:30-13:50	WeBT5.1

Statistics Based Detection and Isolation of UEGO Sensor Faults (I), pp. 2208-2215

Jammoussi, Hassene	Ford Motor Company
Makki, Imad	Ford Motor Company
Filev, Dimitar	Ford
Franchek, Matthew	Univ. of Houston

Stringent emission regulations mandated by California air regulation board (CARB) require monitoring the upstream exhaust gas oxygen (UEGO) sensor for any possible malfunction causing the vehicle emissions to exceed certain thresholds. Six faults have been identified to potentially cause the UEGO sensor performance to deteriorate and potentially lead to instability of the air-fuel ratio (AFR) control loop. These malfunctions are either due to an additional delay or an additional lag in the transition of the sensor response from lean to rich or rich to lean. Current technology detects the faults the same way (approximated by a delay type fault) and does not distinguish between the different faults. In the current paper, a statistics based approach is developed to diagnose these faults. Specifically, the characteristics of a non-normal distribution function are estimated based on the UEGO sensor output and used to detect and isolate the faults. When symmetric operation is detected, a system identification process is employed to estimate the parameters of the dynamic system and determine the type of operation. The proposed algorithm has been demonstrated on real data obtained from both Ford F150 and Mustang V6 vehicles.

13:50-14:10	WeBT5.2

An Ionic-Polymer-Metal-Composite Electrical Model with a Linear Time-Variant Method (I), pp. 2216-2223

Chang, Yi-chu	Texas A&M Univ.
Kim, Won-jong	Texas A&M Univ.

Ionic polymer metal composite (IPMC), categorized as an ionic electroactive polymer (EAP), can exhibit conspicuous deflection with low external voltages (~5 V). This material has been commonly applied in robotic artificial muscles since reported in 1992 because it can be fabricated in various sizes and shapes. Researchers developed numerous IPMC models according to its deflection in response to the corresponding input stimulation. In this paper, an IPMC strip is modeled (1) as a cantilever beam with a loading distribution on the surface, and (2) with system identification tools, such as an autoregressive with exogenous (ARX)/autoregressive moving average with exogenous (ARMAX) model and an output-error (OE) model. Nevertheless, the loading distribution is non-uniform due to the imperfect surface conductivity. Finally, a novel linear time-variant (LTV) modeling method is introduced and applied to an IPMC electrical model on the basis of the internal environment such as surface resistance, thickness, and water distribution related to the unique working principle of IPMC. A comparison between the simulated and the experimental deflections demonstrates the benefits and accuracy of the LTV electrical model.

14:10-14:30	WeBT5.3

Nonlinear Models for Optimal Placement of Magnetically-Actuated Cilia (I), pp. 2224-2230

Banka, Nathan	U. of Washington
Devasia, Santosh	Univ. of Washington

Artificial cilia systems are used for microfluidic manipulation. By analogy to the biological cilia, such systems seek to mix, separate, or propel fluids, particularly in the low-Reynolds number regime, without damaging sensitive samples. An important category of artificial cilia systems is magnetically-actuated artificial cilia, since the driving magnetic field does not interact with many samples of interest. Simulation results are presented to show that linear modeling fails to adequately predict the optimal location due to strong nonlinear effects; using the linear result to select magnet placement results in amplitudes 84% lower than the amplitude with the optimal placement found using the nonlinear model. This represents a substantial loss in efficacy. Since large amplitudes are desirable to enhance flow manipulation, the results illustrate the importance of nonlinear dynamics models in the design of magnet-cilia devices.

14:30-14:50	WeBT5.4

Battery Health Diagnostics Using Retrospective-Cost Subsystem Identification: Sensitivity to Noise and Initialization Errors (I), pp. 2231-2240

Zhou, Xin	Univ. of Michigan
Ersal, Tulga	Univ. of Michigan
Stein, Jeffrey L.	Univ. of Michigan
Bernstein, Dennis S.	Univ. of Michigan

Health management of Li-ion batteries requires knowledge of certain battery internal dynamics (e.g., lithium consumption and film growth at the solid-electrolyte interface) whose inputs and outputs are not directly measurable with noninvasive methods. Therefore, identification of those dynamics can be classified as an inaccessible subsystem identification problem. To address this problem, the retrospective-cost subsystem identification (RCSI) method is adopted in this paper. Specifically, a simulation-based study is presented that represents the battery using an electrochemistry-based battery charge/discharge model of Doyle, Fuller, and Newman augmented with a battery-health model by Ramadass. The solid electrolyte interface (SEI) film growth portion of the battery-health model is defined as the inaccessible subsystem to be identified using RCSI. First, it is verified that RCSI with a first-order subsystem structure can accurately estimate the film growth when noise or modeling errors are ignored. Parameter convergence issues are highlighted. Second, allowable input and output noise levels for desirable film growth tracking performance are determined by studying the relationship between voltage change and film growth in the truth model. The performance of RCSI with measurement noise is illustrated. The results show that RCSI can identify the film growth within 1.5% when the output measurement noise level is comparable to the change in output voltage between successive cycles due to film growth, or when the input measurement noise is comparable to the difference in current that results in a difference in voltage that is the same as the voltage change between successive cycles. Finally, the sensitivity of the performance of RSCI to initial condition errors in the battery charge/discharge model is investigated. The results show that when the initial conditions have an error of 1%, the identified results change by 7%. These results will help with selecting the appropriate sensors for the experiments with the hardware.

14:50-15:10	WeBT5.5

Structural Dynamic Imaging through Interfaces Using Piezoelectric Actuation and Laser Vibrometry for Diagnosing the Mechanical Properties of Composite Materials (I), pp. 2241-2250

Watson, Christopher	Purdue Univ.
Adams, Douglas	Purdue Univ.
Rhoads, Jeffrey	Purdue Univ.

In many engineering applications, diagnostic techniques are needed to characterize the mechanical properties of internal components that are not readily visible at the surface of an object, as in the use of nondestructive testing to detect sub-surface damage in composite materials. Understanding the role of structural interfaces between two bodies is a key factor in developing these diagnostic techniques because the mechanical and geometric properties of the interface determine the degree to which measurements on the surface can be used to interrogate sub-surface components. In this paper, vibration measurements on a polycarbonate material, henceforth referred to as the buffer, are used to characterize the mechanical properties of a polymer particulate composite, henceforth referred to as the target, which is located beneath the buffer. To this end, a three-dimensional laser Doppler vibrometer and piezoelectric inertial actuator are used to measure the broadband response of the two-body structural dynamic system. Because of the importance of the actuator dynamics to the diagnostic measurements, a descriptive model is developed to better understand these dynamics and interpret the results. The longitudinal dynamics of the two-body system are shown to involve stronger coupling between the target and buffer materials as compared to the transverse dynamics. A Complex Mode Indicator Function is then used to extract the modal deflection shapes, and it is shown that the interface between the bodies introduces complexity in the dynamic response. Changes in the surface velocity of the buffer material are also studied as a function of a key mechanical property - the volume fraction of crystals in the target composite material. It is demonstrated that both the linear and nonlinear vibration characteristics of the buffer material change as a function of the composition of the target material, suggesting that a compositional diagnostic procedure is possible using surface vibration measurements.

15:10-15:30	WeBT5.6

Designing Network Motifs in Connected Vehicle Systems: Delay Effects and Stability (I), pp. 2251-2260

Zhang, Linjun	Univ. of Michigan
Orosz, Gabor	Univ. of Michigan

Arising technologies in vehicle-to-vehicle (V2V) communication allow vehicles to obtain information about the motion of distant vehicles. Such information can be presented to the driver or incorporated in advanced autonomous cruise control (ACC) systems. In this paper we investigate the effects of multi-vehicle communication on the dynamics of connected vehicle platoons and propose a motif-based approach that allows systematical analysis and design of such systems. We investigate the dynamics of simple motifs in the presence of communication delays, and show that long-distance communication can stabilize the uniform flow when the flow cannot be stabilized by nearest neighbor interactions. The results can be used for designing driver assist systems and communication-based cruise control systems.

WeBT6	Room 134
Vibrational and Mechanical Systems (Contributed session)	
Chair: Mahmoodi, Nima	The Univ. of Alabama
Co-Chair: Jalili, Nader	Northeastern Univ.

13:30-13:50	WeBT6.1

Modeling the Effects of Heat Transfer Processes on Material Strain and Tension in Roll-To-Roll Manufacturing, pp. 2275-2282

Lu, Youwei	Oklahoma State Univ.
Pagilla, Prabhakar R.	Oklahoma State Univ.

This paper develops governing equations for material strain and tension based on a temperature distribution model when the flexible materials (often called webs) are transported on rollers through heat transfer processes within roll-to-roll (R2R) processing machines. Heat transfer processes are employed widely in R2R systems that contain process operations such as printing, coating, lamination, etc., which require heating/cooling of the moving web material. The heat transfer processes introduce the thermal expansion/contraction of the material and changes in the elastic modulus. Thus, the temperature distribution in the moving material affects the strain distribution in the material. Because of change in strain as well as modulus as a function of temperature, tension in the material resulting from elastic strain is also affected by heating/cooling of the web. To obtain the temperature distribution, two basic heat transfer modes are considered: web wrapped on a heat transfer roller and the web span between two consecutive rollers. The governing equations for strain is then obtained using the law of conservation of mass considering the temperature effects. Subsequently, a governing equation for web tension is obtained by assuming the web is elastic with the modulus varying with temperature; an average modulus is considered for defining the constitutive relation between web strain and tension. Since it is difficult to obtain measurement of tension using load cell rollers within heat transfer processes, a tension observer is designed. To evaluate the developed governing equations, numerical simulations for a single tension zone consisting of a heat transfer roller, a web span, and a driven roller are conducted. Results from these numerical model simulations are presented and discussed.

13:50-14:10	WeBT6.2

Dynamic Modeling and Updating of a Stacked Plate Dynamic System, pp. 2267-2274

Lundstrom, Troy	Northeastern Univ.
Sidoti, Charles	Northeastern Univ.
Jalili, Nader	Northeastern Univ.

The dynamic control of stacked-plate mechanical systems such as circuit board assemblies is a common technical problem that often requires a complete description of the open loop system dynamics prior to controller development. Often, a preliminary finite element model (FEM) of the test article is developed to understand the dynamics of the system to perform a modal test. The results of this modal test must then be used to update the stiffness mass and damping matrices to yield correct FEM frequencies mode shapes and damping. This work describes the mathematical development of a finite element model of a multi-plate test article and proceeds with a model update using differentiated velocity data collected at discrete points on the structure with a laser Doppler vibrometer (LDV) and drive point measurements collected at the excitation location with an impedance head. Using these data, accelerance FRFs were computed and the first three flexible mode shapes were estimated and these shapes were compared to the corresponding FEM shapes using both percent frequency difference and modal assurance criterion (MAC). Several parameters of the system model were modified yielding improved correlation with the experimental results.

14:10-14:30	WeBT6.3

A Linearization-Based Approach to Vibrational Control of Second-Order Systems, pp. 2261-2266

Wickramasinghe, Imiya	Texas Tech. Univ.
Berg, Jordan M.	Texas Tech. Univ.

We present an alternative to averaging methods for vibrational control design of second-order systems. This method is based on direct application of the stability map of the linearization of the system at the desired operating point. The paper focuses on harmonic forcing, for which the linearization is Mathieu's equation, but somewhat more general periodic forcing functions may be handled. When it is applicable, this method achieves significantly greater functionality than previously reported approaches. This is demonstrated on two sample systems. One is the vertically driven inverted pendulum, and the other is an input-coupled bifurcation control problem arising from electrostatic MEMS comb drives.

14:30-14:50	WeBT6.4

Dynamic Response of a Dual-Hoist Bridge Crane, pp. 2283-2290

Maleki, Ehsan	Georgia Inst. of Tech.
Singhose, William	Georgia Inst. of Tech.
Vaughan, Joshua	Univ. of Louisiana at Lafayette
Hawke, Jeffrey	Georgia Inst. of Tech.

Cranes are used in manufacturing facilities, throughout nuclear sites, and in many other applications for various heavy-lifting purposes. Unfortunately, the flexible nature of cranes makes fast and precise motion of the payload challenging and dangerous. Certain applications require the coordinated movement of multiple cranes. Such tasks dramatically increase the complexity of the crane operation. This paper studies the dynamic behavior of a dual-hoist bridge crane. Simulations and experiments are used to develop an understanding of the dynamic response of the system. Various inputs and system configurations are analyzed and important response characteristics are highlighted.

14:50-15:10	WeBT6.5

Active Vibration Control of Resonant Systems Via Multivariable Modified Positive Position Feedback, pp. 2291-2298

Omidi, Ehsan	The Univ. of Alabama
Mahmoodi, Nima	The Univ. of Alabama

One of the predominant difficulties in the theory of distributed structure control systems comes from the fact that these resonant structures have a large number of active modes in the working band-width. Among the different methods for vibration control, Positive Position Feedback (PPF) is of interest, which uses piezoelectric actuation to overcome the vibration as a collocated controller. Modified Positive Position Feedback (MPPF) is later presented by adding a first-order damping compensator to the conventional second-order compensator, to have a better performance for steady-state and transient disturbances. In this paper, Multivariable Modified Positive Position Feedback (MMPPF) is presented to suppress the unwanted resonant vibrations in the structure. This approach benefits the advantages of MPPF, while it controls larger number vibration modes. An optimization method is introduced, consisting of a cost function that is minimized in the area of the stability of the system. LQR problem is also used to optimize the controller performance by optimized gain selection. It is shown that the LQR-optimized MMPPF controller provides vibration suppression in more efficiently manner.

15:10-15:30	WeBT6.6

Relation between End-Effector Impedance and Joint Friction of Statically-Balanced Mechanisms, pp. 2299-2307

Xiu, Wenwu	New Mexico State Univ.
Ma, Ou	New Mexico State Univ.

Statically-balanced mechanisms have been widely used for passive compensation of gravity loads in many applications including neurological rehabilitation and micro-/reduced-gravity simulation. For these applications, it is desirable that the used mechanism has minimal impedance the interacting human can feel. Impedance of a statically-balanced mechanism is contributed by many factors including the payload on the end-effector and the joint friction. This paper studies the relation between the end-effector impedance and the load-dependent joint friction for statically-balanced mechanisms. In the study a load dependent joint friction force model was developed. With the model, contribution of the end-effector load or payload on the joint friction can be evaluated, from which the end-effector impedance of the mechanism caused by the joint friction can be computed. The study results are applied to the analysis of a reduced-gravity simulator to evaluate the effect of the joint friction on the end-effector impedance of the mechanism. The findings of the study can help the assessment of the dynamic performance and also help the optimal design of statically-balanced mechanisms.

WeBT7	Room 138
Fault Detection (Contributed session)	
Chair: Gao, Robert	Univ. of Connecticut
Co-Chair: Ayalew, Beshah	Clemson Univ.

13:30-13:50	WeBT7.1

Observer Based Fault Detection and Identification in Differential Algebraic Equations, pp. 2308-2317

Scott, Jason R.	North Carolina State Univ. Department of Mathematics
Campbell, Stephen L	North Carolina State Univ.

Fault detection and identification (FDI) are important tasks in most modern industrial and mechanical systems and processes. Many of these systems are most naturally modeled by differential algebraic equations. One approach to FDI is based on the use of observers and filters to detect and identify faults. The method presented here uses the least squares completion to compute an ODE that contains the solution of the DAE and applies the observer directly to this ODE. Robustness with respect to disturbances is also addressed by a frequency filtering technique.

13:50-14:10	WeBT7.2

Diagnostics of a Nonlinear Pendulum Using Computational Intelligence, pp. 2318-2325

Samadani, Mohsen	Department of Mechanical Engineering, Villanova Univ. PA
Kwuimy, Cedrick	VILLANOVA Univ. Mech Eng
Nataraj, 'Nat' C.	Villanova Univ.

A novel method has been presented in this paper for the diagnostics of nonlinear systems using the features of the nonlinear response and capabilities of computational intelligence. Four features of the phase plane portrait have been extracted and used to characterize the nonlinear response of a nonlinear pendulum. An artificial neural network has been created and trained using the numerical data for the estimation of parameters of a defective nonlinear pendulum setup. The results show that, with appropriately selected features of the nonlinear response, the parameters of the nonlinear system can be estimated with an acceptable accuracy.

14:10-14:30	WeBT7.3

Fault Modelling for Hierarchical Fault Diagnosis and Prognosis, pp. 2326-2335

Zhang, Jiyu	OSU
Rizzoni, Giorgio	Ohio State Univ.
Ahmed, Qadeer	CAR, OSU

Fault modeling ,which is the determination of the effects of a fault on a system, is an effective way for conducting failure analysis and fault diagnosis for complex system. One of the major challenges of fault modeling in complex systems is the ability to model the effects of component-level faults on the system. This paper develops a simulation-based methodology for failure analysis through modeling component-level fault effect on the system level, with application to electric vehicle powertrains. To investigate the how a component fault such as short circuit in a power switch or in a motor winding affects the vehicle system, this paper develops a detailed simulator which allows us to see system and subsystem failure behaviors by incorporating fault models in the system. This fault modeling process provides useful knowledge for designing a reliable and robust fault diagnosis and prognosis procedures for electrified powertrains.

14:30-14:50	WeBT7.4

Fault Diagnosis on a Digital-Displacement Pump/Motor, pp. 2336-2345

Wang, Chunjian	Clemson Univ.
Ayalew, Beshah	Clemson Univ.
Filipi, Zoran	Clemson Univ.

A Digital-Displacement Pump/Motor (DDPM) has recently been proposed as an attractive candidate for hydraulic powertrain applications. A DDPM uses solenoid-controlled valves for each cylinder. This provision offers flexibility of control that can be exploited to boost system efficiency by matching individual cylinder operations with load conditions. However, the added complexity from individual cylinder control necessitates mechanisms for fault diagnosis and control reconfiguration to ensure reliable operation of the DDPM. Furthermore, available measurements are often limited to supply and return line pressures, shaft angle and speed. In this paper, it is shown that, with only these measurements, individual cylinder faults are structurally unobservable and un-isolable by the use of a system model relating the cylinder faults to the shaft dynamics. To overcome this difficulty, the phase angles at which possible individual cylinder faults can begin to affect the shaft dynamics are tabulated for each cylinder, and a fault indicator that is akin to a shaft acceleration fault is modeled and estimated via a fast sliding mode observer. Simultaneous detection and isolation of individual cylinder faults can be achieved using this fault indicator and a table of fault begin angles. Illustrative examples are included from simulations of a 5 cylinder DDPM to demonstrate this diagnosis process.

14:50-15:10	WeBT7.5

An Experimentally Validated Model for Reciprocating Compressor Main Bearings with Application to Health Monitoring, pp. 2346-2354

Holzenkamp, Markus	Rochester Inst. of Tech.
Kolodziej, Jason	Rochester Inst. of Tech.
Boedo, Stephen	Rochester Inst. of Tech.
Delmotte, Scott	Dresser-Rand Company

A simple model of the compressor main bearings was created using the mobility method. The model allows for the simulation of the three loading conditions of the compressor as well as accounting for the geometry of the connecting rod and crankshaft. The simulation was then compared against the results from measuring the orbit of the crankshaft. This is a simple and low cost way to monitor the main bearings without installing sensors directly in the bearing sleeve. The results show good qualitative agreement to move forward with developing the model and sensor application with the end goal of application to health monitoring.

15:10-15:30	WeBT7.6

Failure Detection and Trend Prediction of Rolling Element Bearing Based on Approximate Entropy, pp. 2355-2361

Wang, Peng	Univ. of Connecticut
Gao, Robert	Univ. of Connecticut
Huaqing, Wang	Beijing Univ. of Chemical Tech.
Yuan, Hongfang	Beijing Univ. of Chemical Tech.

By quantifying the regularity vibration signals measured on rolling bearings, Approximate Entropy (ApEn) provides an effective measure for characterizing the structural degradation of bearings, and the severity of the defect. This paper investigates the relationship between ApEn and different failure modes of bearings. It is shown that. ApEn values decrease with the degradation of bearing defects. After introducing the theoretical background, experimental analysis are presented to quantify variation of ApEn values as a measure for defect mode and severity. A life cycle experiment is introduced to evaluate a defect growth precondition model based on regression analysis and Genetic Algorithm. Results show that ApEn is effective for bearing defect diagnosis and remaining service life prognosis.

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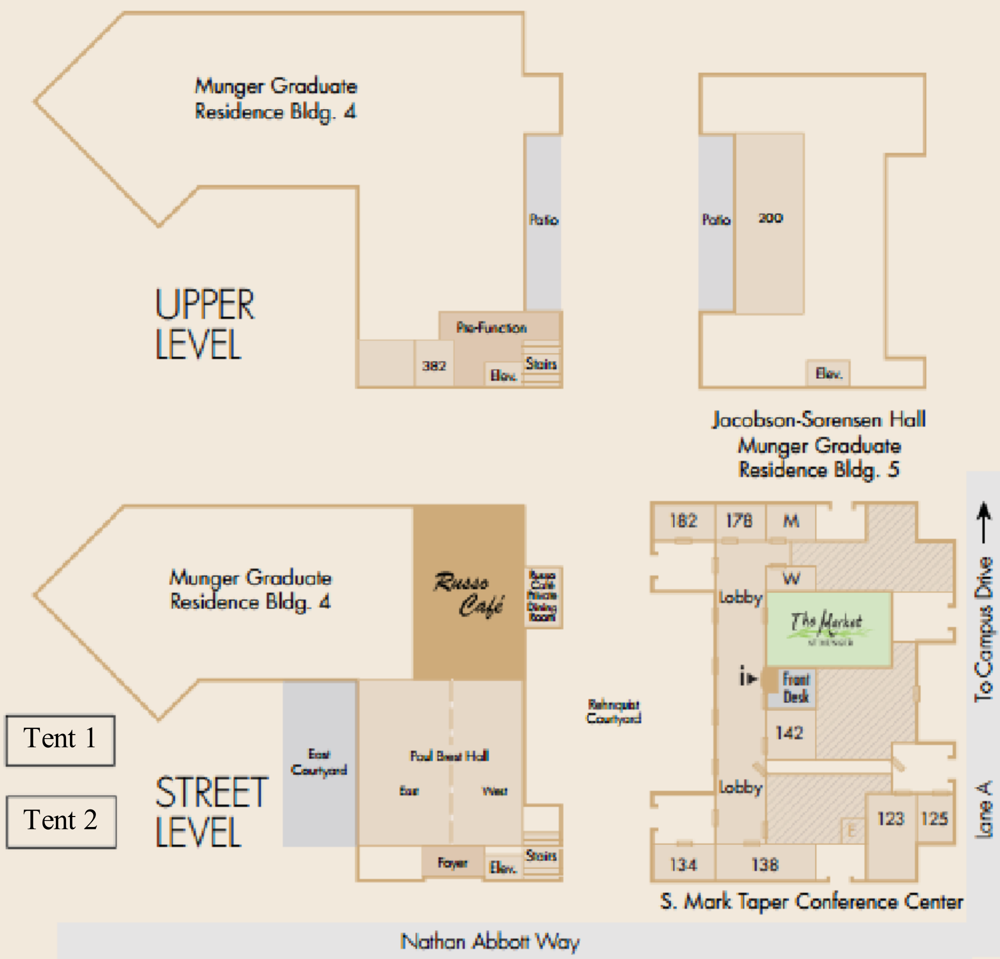

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