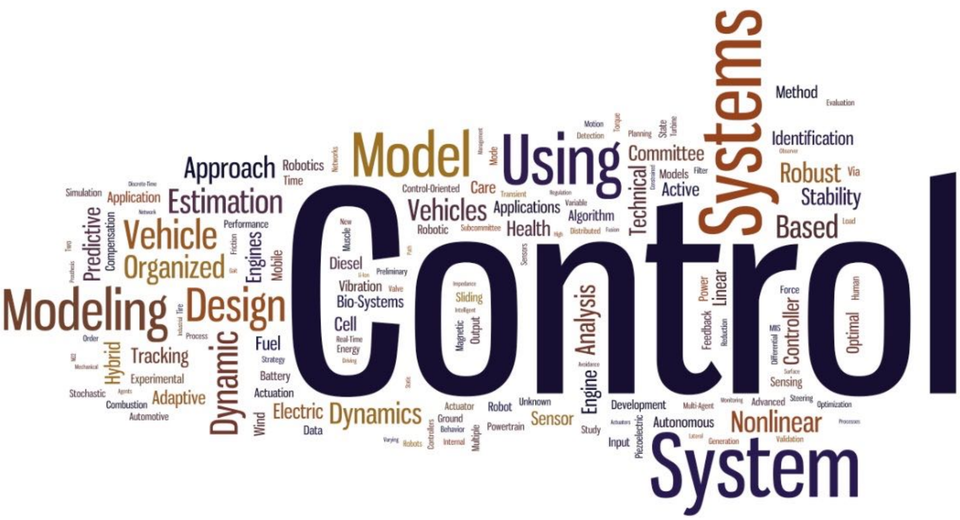
DSCD Newsletter Winter 2018

December 21, 2018



DYNAMIC SYSTEMS AND CONTROL DIVISION NEWSLETTER

Editor's Note

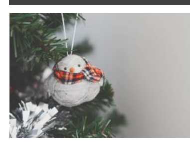
Dear colleagues,

This issue of ASME DSCD Newsletter contains the feature "The 2018 ASME Dynamic Systems and Control Conference (DSCC)" by Xiaobo Tan, General Chair of DSCC 2018. The feature summarizes the conference statistics, the technical and social programs, and recognitions of the Division and conference awardees this year. The first feature is followed by a summary of the Division Meeting held at DSCC 2018. Santosh Devasia, Chair of the Honors and Awards Committee, provides us with the status of the Division and ongoing future planning. In the third feature of the issue, Huei Peng, the 2018 Nyquist Lecturer, and Anna G. Stefanopoulou, the 2018 Charles Stark Draper Innovative Practice Awardee, share their research trajectories and advice to junior researchers. This issue contains a Q&A feature with Jun Ueda, chair of the Division's Mechatronics Technical Committee (TC). Peiman Naseradinmousavi, assistant professor of San Diego State University, discusses an analytical and experimental predictor-based time delay control of a robot manipulator. And Nima Lotfi, assistant professor of Southern Illinois University Edwardsville, introduces a collaborative effort to advance mechatronics and robotics education.

This winter issue would not have been possible without the help of many people. Jianguo Zhao, Associate Editor (AE), worked tirelessly to have created the features on People in Dynamic Systems and Control, on TC Mechatronics, and on Education. Peter Meckl, Editor of the DSC Magazine, Jingang Yi, and the DSCD Executive Committee, provided tremendous support and pivotal suggestions on content creation, especially during the recent upgrade of the Division's email list. I wish also to thank all contributors to this Newsletter, for sharing with us your stellar research, instrumental scholarship, and marvelous service. As I graduate from the Newsletter Editorial Office in 2018, Jianguo will be your new Editor in 2019. Two talented new AEs will also join the team: Tuhin Das, associate professor, University of Central Florida, as senior AE; and Huazhen Fang, assistant professor, University of Kansas, as junior AE. Please continue to support the Newsletter for serving you to its best capability and beyond in 2019!

Happy Holidays!
Xu Chen

IN THIS ISSUE



The 2018 ASME Dynamic Systems and Control Conference (DSCC)

Xiaobo Tan, Michigan State University

General Chair, DSCC 2018

Close to 400 people attended the 2018 ASME Dynamic Systems and Control Conference (DSCC) held at the Hyatt Regency Atlanta, on September 30 – October 3, 2018. DSCC is the flagship conference of the ASME Dynamic Systems and Control Division (DSCD), and we celebrated its eleventh edition this year.

TECHNICAL PROGRAM

The conference opened with five workshops that focused on emerging and timely topics on the afternoon of September 30. The five workshops were: "From data to models and decisions in engineering systems," organized by Professor Annalisa Scacchioli from Rutgers University and Professor Mahdi Shahbakhti from Michigan Technological University; "Enhancing energetic performance for mobile and wearable robotic systems," organized by Professors Anirban Mazumdar and Aaron Young from Georgia Tech; "Connected and automated vehicles," organized by Professor Mahdi Shahbakhti from Michigan Technological University and Professor Hosam Fathy from Pennsylvania State University; "The future of mechatronics and robotics education," organized by Professor Vikram Kapila from New York University, Professor Michael A. Gennert from Worcester Polytechnic Institute, Professor James Mynderse from Lawrence Technological University, and Professor Nima Lotfi from Southern Illinois University Edwardsville; and "Autonomous control for rotorcraft operation," organized by Professor Cornel Sultan from Virginia Tech. These workshops attracted over 80 attendees.

This year's regular technical program contained 238 original papers organized in 9 invited sessions and 33 contributed sessions, which spanned all core areas of interest to the dynamic systems and control community. These papers were presented during two and a half days.

The conference featured four exciting plenary talks. Professor Huei Peng from University of Michigan delivered his Nyquist Lecture, "How control theories were used to improve energy and safety of automotive systems"; Professor Marcia O'Malley from Rice University gave a talk titled "Towards robots that teach and learn through physical human-robot interaction"; Professor Roberto Horowitz from University of California, Berkeley, delivered his Oldenburger Lecture, "Modeling, control and estimation of traffic road networks" and Professor Magnus Egerstedt from Georgia Tech spoke about "Long duration autonomy and constraint-based coordination of multi-robot systems."

AWARDS

A number of colleagues were honored at the Awards Ceremony, right before the banquet on the night of October 2. Professor Roberto Horowitz from University of California, Berkeley, was the recipient of this year's Rufus T. Oldenburger Medal, which is a prestigious ASME society-level award for lifetime achievements in automatic control. Three division-level awards were presented: Professor Tsu-Chin Tsao from University of California, Los Angeles, received the Henry M. Paynter Outstanding Investigator Award, for his "seminal contributions in feedforward, repetitive and adaptive control areas and their applications"; Professor KokMeng Lee from Georgia Tech received the Michael J. Rabins Leadership Award, for his "long-lasting impact on the DSCD community in the intelligent mechatronics field"; Professor

Plenary Talks, DSCC 2018

Professor Magnus Egerstedt
Georgia Tech.
Plenary talk: Long duration autonomy and constraint-based coordination of multi-robot systems

Professor Huei Peng, University of Michigan
Nyquist Lecture: How control theories were used to improve energy and safety of automotive systems

Professor Roberto Horowitz
University of California, Berkeley
Oldenburger Lecture: Modeling, control and estimation of traffic road networks

Professor Marcia O'Malley
Rice University
Plenary talk: Towards robots that teach and learn through physical human-robot interaction

Anna Stefanopoulou from University of Michigan, Ann Arbor, received the Charles Stark Draper Innovative Practice Award, for her "sustained innovative and impactful contributions to the modeling, analysis and control of advanced vehicle powertrain systems." This year's Rudolf Kalman Best Paper Award went to Kræn Vodder Busk, Mogens Blanke, Lars Eriksson, and Morten Vejlgaard-Laursen, for their paper "Control-oriented model of molar scavenge oxygen fraction for exhaust recirculation in large diesel engines" published in the February 2017 issue of ASME Journal of Dynamic Systems, Measurement and Control. Professor Huei Peng from University of Michigan was this year's Nyquist Lecturer.

At the Awards Ceremony, five Best Student Paper Award finalists were also honored: Sahand Sadeghi from Clemson University, for their paper "The effect of nonlinear springs in jumping mechanism"; Poya Khalaf from Cleveland State University, for their paper "Development and experimental validation of an energy regenerative prosthetic knee controller and prototype"; Abhinav Tripathi from University of Minnesota, for their paper "Experimental investigation and analysis of auto-ignition combustion dynamics"; Bingjie Hao from Huazhong University of Science and Technology and Georgia Tech, for their paper "Eddy-current dynamic model for simultaneous geometrical and material parameter measurements of magnetic materials," and Huan Yu from University of California, San Diego, for their paper "Stabilization of traffic flow with autonomous vehicles." The winner of the 2018 DSCC Best Student Paper Award was Poya Khalaf.

SPECIAL PROGRAMS

Aside from the Best Student Paper Competition, the conference offered several other programs focused on students. In particular, two separate professional and networking events were organized, where students met with mentors from academia and industry to receive career advice. For early-career faculty members, postdocs, and graduate students, an Early Academic Career Panel was organized, where past NSF CAREER

Student Best Paper: Students and Young Members Chair, Professor Vaibhav Srivastava (left) with the Best Student Paper finalists. 2018 DSCC Best Student Paper Award winner was Poya Khalaf.

Awardees at DSCC 2018

Top row (left to right): Professor Tsu-Chin Tsao receiving the Paynter Award from Professor Santosh Devasia, Vice Chair of the Honors and Awards Committee; Professor Kok-Meng Lee from Georgia Tech receiving the Michael J. Rabins Leadership Award; Professor Anna Stefanopoulou from University of Michigan, Ann Arbor, receiving the Charles Stark Draper Innovative Practice Award; Professor Roberto Horowitz from University of California, Berkeley, receiving the Rufus T. Oldenburger Medal.

Bottom row (left to right): Dr. Lars Eriksson receiving the Kalman Best Paper Award on behalf of all co-authors; Professor Huei Peng is the Nyquist Lecturer of DSCC 2018.

Georgia Tech Campus Tour: Pictures showing 1) the Robotarium Lab directed by Professor Magnus Egerstedt, 2) the Bio-Robotics Lab directed by Professor Jun Ueda, and 3) the Intelligent Machine Dynamics Lab directed by Professor Wayne Book, 4) Exoskeleton and Prosthetics Lab directed by Professor Aaron Young.

Awardees shared their insight and tips in obtaining their CAREER grants. At a special NSF funding session, the conference attendees also got a great opportunity to learn about various relevant funding programs at NSF and interact directly with a number of Program Directors. The slides presented by the NSF Program Directors are now available at the 2018 DSCC website, under the tab "Program."

Another highlight of the conference was a tour to Georgia Tech campus on the afternoon of October 3, where attendees got a chance to see the exciting research carried out at six robotics and control labs. These included the Exoskeleton and Prosthetics Lab directed by Professor Aaron Young, the Intelligent Machine Dynamics Lab directed by Professor Wayne Book, the Bio-Robotics Lab directed by Professor Jun Ueda, the Soft Robotics Lab directed by Professor Frank Hammond, the Medical Robotics Lab directed by Professor Jaydev Desai, and the Robotarium Lab directed by Professor Magnus Egerstedt.

SOCIAL PROGRAM

The conference offered many opportunities for attendees to catch up and network, including the welcome reception, awards ceremony and banquet, and networking breakfast and coffee breaks every day. A number of meetings, including the Division general meeting and various technical committee meetings, were held at the conference.

We wanted to thank the authors for contributing their quality work, the foundation of the technical program; the DSCD Technical Committees for organizing invited sessions; and the reviewers and the Conference Editorial Board members for reviewing the submissions and providing valuable feedback. We wanted to thank the sponsors for their generous support to the conference. Last but not least, we wanted to recognize the tireless effort of Organizing Committee members including several key ASME staff members.

Let's look forward to 2019 DSCC, Park City, Utah!

The 194th Division Meeting

Santosh Devasia, University of Washington
Chair of the Honors and Awards Committee

The division held its 194th Division Meeting at Atlanta, Georgia on October 1, 2018, the first day of the 2018 Dynamic Systems and Control Conference (DSCC). Anna Stefanopoulou, Professor of Mechanical Engineering, University of Michigan and Chair of the DSCD Executive Committee, led the meeting. The division discussed recent changes related to dynamic systems and controls at NSF, and the division's sponsored conference activities. Edmond Valpoort, the ASME Liaison to DSCC gave an update on the DSCC conferences. Both the attendance numbers and quality (acceptance rate) of papers have been improving. The next DSCC conferences are scheduled to be held in Park City, Utah (2019), Hartford, Connecticut (2020), and Austin, Texas (2021). The division thanked and recognized its past office bearers. The division

194th Division Meeting at DSCC 2018

will have its next public Division Meeting on the first evening of the 2019 American Conference (ACC) in July in Philadelphia.

People in Dynamic Systems and Controls

In this article, we speak with two of the awardees at the 2018 DSCC conference: Dr. Huei Peng, the Nyquist Lecturer, and Dr. Anna G. Stefanopoulou, the Charles Stark Draper Innovative Practice Awardee.

Dr. Huei Peng received his Ph.D. in Mechanical Engineering from the University of California, Berkeley in 1992. He is now a Professor at the Department of Mechanical Engineering at the University of Michigan. His research interests include adaptive control and optimal control, with emphasis on their applications to vehicular and transportation systems. His current research focuses include design and control of electrified vehicles, and connected/automated vehicles. In the last 10 years, he was involved in the design of several military and civilian concept vehicles, including FTTS, FMTV, Eaton/Fedex, and Super-HUMMWV—for both electric and hydraulic hybrid concepts. He served as the US Director of the DOE sponsored Clean Energy Research Center—Clean Vehicle Consortium, which supports more than 30 research projects related to the development of clean vehicles in the US and in China. He currently serves as the Director of Mcity, which studies connected and autonomous vehicle technologies and promotes their deployment. Huei Peng has been an active member of the Society of Automotive Engineers (SAE) and the American Society of Mechanical Engineers (ASME). He is both an SAE fellow and an ASME Fellow. He is a ChangJiang Scholar at the Tsinghua University of China.

Q: How did you enter the field of automated and connected vehicles?

Huei: I started in the field of automated and connected vehicles in 1988, when I joined UC Berkeley to study highway automation. I am stilling working on many of the challenging problems for highly automated vehicles, including perception, compensation for nonlinearities and delays, and decisions under highly uncertain environment.

Q: What's your advice for junior researchers in the DSCD community on career development?

Huei: My main advices to young researchers in the field of controls are (i) find your passion, identify the grand challenges you want to help solving, and (ii) be a life-long learner to gather knowledge to solve those challenging problems.

Dr. Anna Stefanopoulou is the William Clay Ford Professor of Manufacturing at the University of Michigan. She was an assistant professor at the University of California, Santa Barbara and a technical specialist at Ford Motor Company. She is an ASME (08), an IEEE (09) and a SAE (18) fellow, an elected member of the Executive Committee of the ASME Dynamics Systems and Control Division and the Board of Governors of the IEEE Control Systems Society. She has received multiple awards in powertrain control technology and was a member of a U.S. National Academies committee on Light Duty Vehicle fuel efficiency. She has coauthored a book, 20 US patents, 250 publications (5 of which have received awards) on estimation and control of internal combustion engines and electrochemical processes such as fuel cells and batteries.

Q: How did you enter the field of powertrain control?

Anna: I specialized in ship propulsion while studying for my Diploma in Naval Architecture and Marine Engineering in Athens' Greece. Then I got a scholarship from the University of Michigan in autonomous navigation in the great lakes. The automotive industry in SE MI really absorbed my interests and so I decided to switch to Electrical Engineering and study model-based control of engines.

I worked at Ford where I implemented many new engine control functions in beautiful cars and powerful engines. We worked around the clock; with Dearborn sending algorithms to Europe, and getting back the data and retuning the algorithm just in time for EU colleagues to have it as they were waking up.

As Assistant Prof at UC Santa Barbara I worked on automated braking of heavy-duty vehicles. These efforts were the birth of the CAVs era we are experiencing right now. I finally moved to UMICH and I decided to dive in a completely new territory, namely Fuel Cell control or balance of plant. Researching battery management was also an exciting new area.

Q: What do you see as some of the challenges and opportunities in powertrain control? And what's your advice for junior researchers in the DSCD community to advance the field?

Anna: I find the main challenge in the field is the lack of real sensors and the false belief that virtual sensors can substitute them. I encourage junior researchers to work with industry and look for real-world problems.

We thank the guests Dr. Huei Peng and Dr. Anna Stefanopoulou for sharing their insights to the community!

A Look Inside the ASME Dynamic Systems & Control Division (DSCD)

— The Mechatronics Technical Committee and its Operation

The DSCD currently has six technical committees (TCs) covering, respectively, *Automotive and Transportation Systems (ATS)*, *Energy Systems*, *Biosystems and Healthcare*, *Mechatronics*, *Robotics*, and *Vibrations*. In this feature, we speak with Dr. Jun Ueda, Associate Professor and Woodruff Faculty Fellow in the G.W.W. School of Mechanical Engineering at Georgia Institute of Technology and Chair of the *DSCD Mechatronics TC*, about the TC's organization and operation.

Dr. Ueda received the B.S., M.S., and Ph.D. degrees from Kyoto University, Kyoto, Japan, in 1994, 1996, and 2002 all in Mechanical Engineering. From 1996 to 2000, he was a Research Engineer at the Advanced Technology Research and Development Center, Mitsubishi Electric Corporation, Japan. He was an Assistant Professor of Nara Institute of Science and Technology, Japan, from 2002 to 2008. During 2005-2008, he was a visiting scholar and lecturer in the Department of Mechanical Engineering, Massachusetts Institute of Technology. He joined the G. W. Woodruff School of Mechanical Engineering at the Georgia Institute of Technology as an Assistant Professor in 2008. He served as the Director for the Robotics PhD Program at Georgia Tech for 2015-2017.

He received a Fanuc FA Robot Foundation Best Paper Award in 2005, IEEE Robotics and Automation Society Early Academic Career Award in 2009, and Advanced Robotics Best Paper Award in 2015. He currently serves as an Associate Editor for the IEEE RAS Robotics and Automation Letters, International Journal of Intelligent Robotics and Applications, and IEEE Transactions on Robotics. He is the author of Cellular Actuators: Modularity and Variability in Muscle-Inspired Actuation, Butterworth-Heinemann, 2017, and Human Modeling for Bio-Inspired Robotics, Academic Press, 2017. He is a member of ASME and a senior member of IEEE.

Q: Could you tell us a bit about the overall scope of the TC?

Jun: The Mechatronics TC was established in 2001. The TC consists of a group of primary members and general members to cover board technical areas in mechatronics including design and modeling of mechatronic systems, control applications, sensors and sensing network systems, bio-mechanical and human-machine systems, industrial applications, manufacturing, MEMS and Nano Technology, Mobile Robots, Automotive Systems.

Q: How large is the TC now? How did it grow to the current state?

Jun: The TC currently has more than 150 members. Historically, it has been one of the most active TCs in the DSCD. The TC has been continuously growing through a variety of academic activities.

Q: What are the roles of the TC officers?

Jun: The Technical Committee Board will consist of the following five officers: Chair, Vice Chair, Award Committee Chair, Conference Chair, and Secretary. The Chair is responsible for day-to-day operations of the TC and is expected to represent the TC at the DSCD affairs as well as the joint activities with other societies such as IEEE. The Vice Chair is to supervise various initiatives that will help the TC grow and better meet the needs of the TC members. The Award Committee Chair arranges the selection of best paper and best student paper awards given by the TC. The Conference Chair is responsible for supervising the organization of technical sessions at various conferences. The Secretary maintains meeting minutes including list of attendees. The term for each officer position is one year. At the end of the term of each officer, the Chair will automatically become the Award Committee Chair, the Vice Chair for the Chair, the Conference Committee Chair for the Vice-Chair, with the Secretary selected from the primary members based on the majority vote of the Technical Committee.

Q: How often do the TC members meet? How is a TC meeting organized?

Jun: The TC meets at Dynamic Systems and Control Conference (DSCC), American Control Conference (ACC), and IEEE/ASME International Conference on Advanced Intelligent Mechatronics (AIM). At the meetings, the TC reports past activities, approves officer elections, and discusses future TC activities. In the TC meeting at DSCC 2018, a speed networking event was organized for young faculty members.

Q: Any other activities for the TC?

Jun: The TC organizes invited and special sessions at DSCC, ACC, and AIM. Also, the TC members actively organize special issues and focused sections such as for IEEE/ASME Transactions on Mechatronics (TMECH), International Journal of Intelligent Robotics and Applications (IJIRA) and Journal of Dynamic Systems, Measurement and Control (JDSMC). The TC annually presents the best paper award and best student paper award selected by the Award Committee at DSCC. Many TC members are involved in the organization of ACC, DSCC, AIM and IFAC conferences as well as the editorial boards for TMECH, IJIRA and JDSMC. Several TC members served as a program director in the directorate of engineering at NSF.

Q: How can interested division members get engaged with the TC?

Jun: Interested division members are welcome to attend the TC meeting at either ACC, DSCC or AIM, or contact one of the TC officers.

Thank you Jun!

Analytical and Experimental Predictor-Based Time Delay Control of a High-DOF Robot Manipulator

M. Bagheri[1,2], P. Naseradinmousavi[1**], and M. Krstic[2]

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[1] Department of Mechanical Engineering, Dynamic Systems and Control Laboratory (DSCL), San Diego State University

[2] Department of Mechanical and Aerospace Engineering, University of California, San Diego

Robot manipulators are widely used in various applications to track desired trajectories, particularly in telemanipulation systems, on the account of their reliable, fast, and precise motions in executing tasks such as moving debris and turning valves. Remote manipulators provide the capability of executing tasks safely at an unreachable/dangerous location while they are subject to large input delays as with many engineering systems. Interest in delay, as a common dynamic phenomenon, is driven by applications in modeling and control of traffic systems, teleoperators, vehicles, and robot manipulators. The detrimental impact of time delay is well-established, which plays the most significant role in degrading remote perception and manipulation. Using common control approaches on such delay systems can cause not only poor control performance, but also catastrophic instability in engineering applications. Large input delays often arise from communication delay between sensor and actuator, or from time-consuming computational burden of multi-agent networks. For instance, the foremost concern of vision-based control is tackling the delay introduced by image acquisition and image processing, as shown in Figure 1.

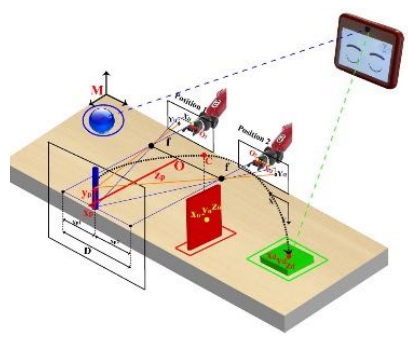


Figure 1: The computational delay through image processing.

The robot joint's configurations, being studied here, are shown in Figure 2.

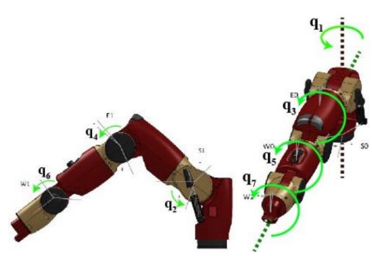


Figure 2: The 7-DOF Baxter robot.

Mathematical Modeling

The robot is a redundant one and has 7-DOF. We derived its mathematical model through the Euler-Lagrange equation:

$$M(q)\ddot{q} + C(q,\dot{q})\dot{q} = \tau - \varphi(q)$$

where, $q, \dot{q}$, and $\ddot{q} \in \mathbb{R}^7$ are angles, angular velocities, and accelerations of joints, respectively, and $\tau \in \mathbb{R}^7$ indicates the vector of joints' driving torques. Also, $M(q) \in \mathbb{R}^{7\times7}$, $C(q,\dot{q}) \in \mathbb{R}^{7\times7}$, and $\varphi(q) \in \mathbb{R}^7$ are the mass, Coriolis, and gravitational matrices, respectively. The experimental validation of such a coupled nonlinear mathematical model is a necessity to be carried out in order to examine the accuracy of the formulation and then possibly refine the model.

We hence recorded the joints' torques to be compared with the ones computed through the interconnected equations (Figure 3).

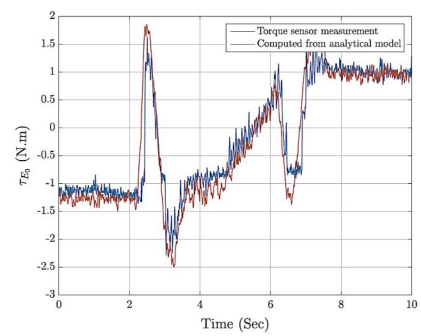


Figure 3: A sample of comparison between the experimentally measured and nominal analytical torques used in driving the joints.

Designing the Predictor-Based Controller

Dealing with unmodeled dynamics including joints' friction and backlash, along with strong dynamic interconnections, would cause a complicated problem of designing robust and computationally efficient control schemes to avoid the large delays. Therefore, we formulate a predictor-based controller for a multi-input nonlinear system, in the presence of input delay, to stabilize the closed-loop system.

In order to demonstrate the generality of our approach, consider the following general multi-input nonlinear system with a constant input delay,

$$\dot{\boldsymbol{X}}(\boldsymbol{t}) = \boldsymbol{f}(\boldsymbol{X}(\boldsymbol{t}), \boldsymbol{U}_{\boldsymbol{1}}(\boldsymbol{t}-\boldsymbol{D}), \ldots, \boldsymbol{U}_{\boldsymbol{m}}(\boldsymbol{t}-\boldsymbol{D}))$$

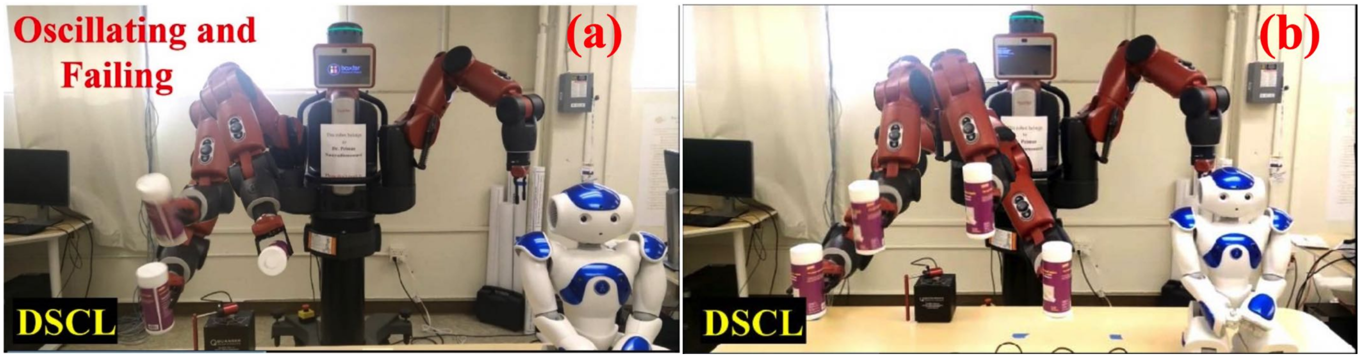


Figure 4: (a) The robot fails to track the desired trajectory without a predictor in the presence of input delay; (b) A stable obstacle-avoidance pick-and-place task with input delay using the predictor-based controller.

where $\boldsymbol{X} \in \mathbb{R}^n$ is the vector of states, $\boldsymbol{U_1}, \dots, \boldsymbol{U_m} \in \mathbb{R}$ are the control inputs, $\boldsymbol{D} > \boldsymbol{0}$ is an input delay, and $\boldsymbol{f}: \mathbb{R}^n \times \mathbb{R}^m \to \mathbb{R}^n$ is a locally Lipschitz vector field. We assume that a feedback law $\boldsymbol{U_i(t)} = \boldsymbol{\kappa_i(X(t))}$ is known such that the functions $\boldsymbol{\kappa_i}: \mathbb{R}^n \to \mathbb{R}$ globally asymptotically stabilize the delay-free system; $\dot{\boldsymbol{X}}(\boldsymbol{t}) = \boldsymbol{f(X(t), \kappa(X(t))}$ is globally asymptotically stable in the absence of delay. Therefore, in the delay system, the control law needs to be as follows:

$$\boldsymbol{U_i(t-D) = \kappa_i(X(t))}$$

which can be expressed as

$$\boldsymbol{U_i(t) = \kappa_i\big(X(t+D)\big) = \kappa_i(P(t))}$$

where $\boldsymbol{P(t)}$ is the *D*-time units ahead predictor of $\boldsymbol{X(t)}$. The predictor feedback law for the system is given by,

$$\boldsymbol{P(t) = X(t) + \int_{t-D}^{t} f(P(\theta), U_1(\theta), \dots, U_m(\theta))d\theta}$$

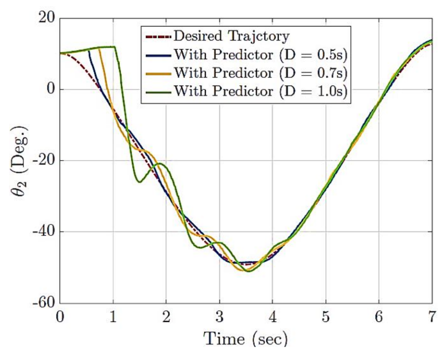
with the following initial conditions for the integral:

$$\boldsymbol{P(\theta) = X(0) + \int_{-D}^{\theta} f(P(s), U_1(s), \dots, U_m(s))ds}$$

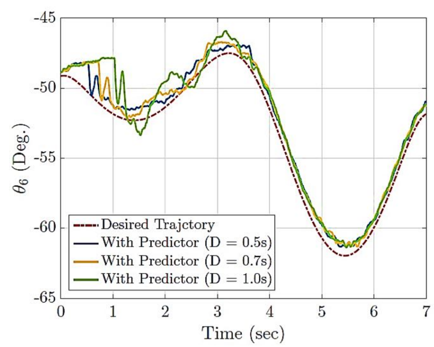
where $\boldsymbol{\theta} \in [-\boldsymbol{D}, \boldsymbol{0}]$. Using transport PDEs (first-order hyperbolic PDEs) for the actuators' states, as well as an equivalent PDE representation of the predictor states, we derived the stability proof of the closed-loop system with input delay based on an equivalent representation of the plant.

Experimental Results

We implement the predictor-based controller for the 7-DOF Baxter manipulator, as a case study, through a pick-and-place task, while input delays are similar in all input channels. We first reveal the destabilizing effect of input delay on the control of the manipulator, as shown in Figure 4(a), and then discuss the effect of incremental delay on the stability of the robot. We take the advantage of the predictor-based controller, using some Theorems and Corollaries, in order to globally asymptotically stabilize the manipulator. In order to examine the effect of delay's magnitude, the experiments are carried out in the presence of 0.5s, 0.7s, and 1.0s input delays. Note that having more than 1.0s input delay, through this operation, is not logical since the whole operational time is 7.0s. Shown in Figures 5 and 6 are some of joints' angels and torques, respectively.

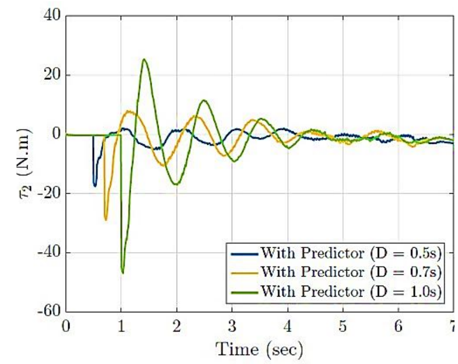


(a)

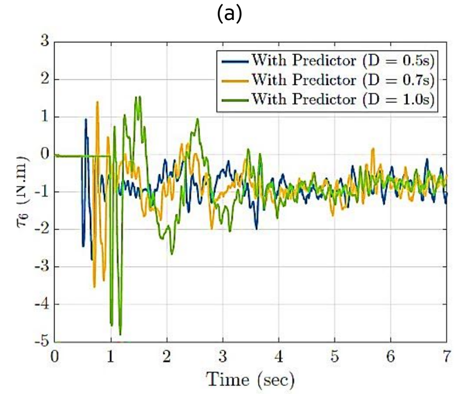


(b)

Figure 5: Some of experimental Joints' trajectories using the predictor-based compensator.



(a)



(b)

Figure 6: Some of experimental joints' torques using the predictor-based compensator.

As shown in Figure 6, there is no control torque before $\boldsymbol{t}$ = *D*s and consequently, the robot remains stationary (Figure 5). Therefore, the errors expectedly emerge within $\boldsymbol{t} \in [\mathbf{0}, \mathbf{D})$, in particular for the joints 2, 4, and 7 (Figures 1 and 5). At $\boldsymbol{t}$= *D*s, the manipulator starts following the desired trajectories using the predictor-based controller. Figures 4(b) and 6 present an acceptable performance of the predictor-based controller since the tracking errors converge to almost zero after 4.0s. After $\boldsymbol{t}$ = *D*s, the manipulator begins to oscillate in order to follow, almost perfectly, the desired trajectories using the considerable initial control torques. On the other hand, the control torques peak at $t = D$s and then decline by the decremental tracking errors (Figure 6). As can be observed in Figure 5, the tracking errors begin to decrease from $t = D$s, but they undesirably oscillate around the origin despite the fact that Theorems and Corollaries guarantee the asymptotic convergence of the tracking errors to zero subject to any large delay. Figures 7, 8, and 9 present the experimental tracking errors for the time delays of D = 0.5s, D = 0.7s, and D = 1.0s, respectively.

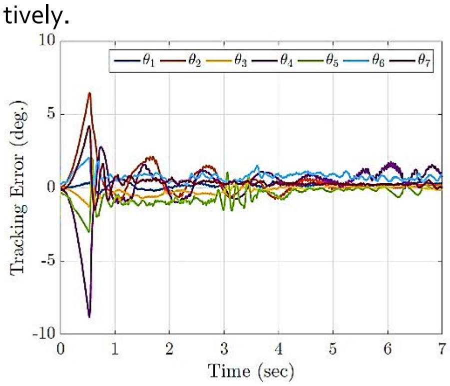


Figure 7: The experimental tracking errors subject to the predictor-based controller in the presence of 0.5s input delay.

The negligible experimental tracking errors mainly root on the inaccuracy of sensors and actuators. Moreover, the prediction-based process builds upon the system mathematical model and therefore, any error in the modeling process, which is negligible in our case study, yields more prediction and tracking errors. Figure 10 presents the simulation results for D = 1.0s. The results reveal that the tracking errors asymptomatically converge to zero, as expected.

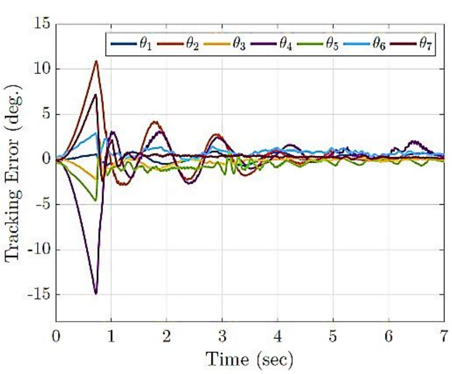


Figure 8: The experimental tracking errors subject to the predictor-based controller in the presence of 0.7s input delay.

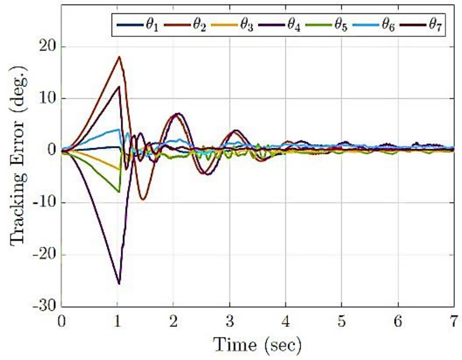


Figure 9: The experimental tracking errors subject to the predictor-based controller in the presence of 1.0s input delay.

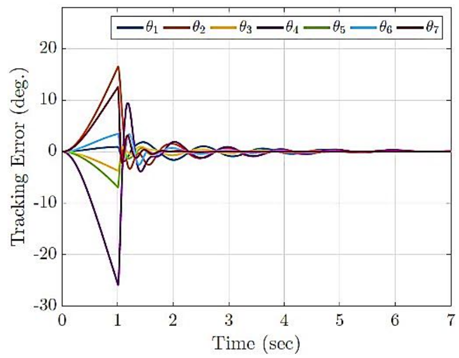


Figure 10: The simulated tracking errors subject to the predictor-based controller in the presence of 1.0s input delay.

Summary

Throughout this effort, we presented the formulation and implementation of a predictor-based controller for a general highly interconnected nonlinear system subject to the time-invariant input delay, and then the controller was implemented for the 7-DOF Baxter manipulator as a case study. Figure 4(a) revealed the destabilizing effects of different input delays. Toward designing the controller, we established the forward completeness and Input-to-State Stability (ISS) properties of the system. We then formulated the predictor-based controller, and investigated the effects of large input delays on the control of Baxter robot. The experimental results revealed that the manipulator becomes stable using the predictor-based controller and tracks, as expected, the desired joint-space trajectories in the presence of large input delays.

We also established that the tracking errors, subject to the predictor-based controller, asymptotically converge almost to zero. The fluctuations observed for the errors mainly root on the inaccuracy of sensors and actuators in addition to the error involved with the mathematical modeling process. Although, the simulation results presented the asymptotic convergence of the tracking errors to zero.

The principal results of this research work can be summarized as follows:

1) The system is forward complete and Input-to-State Stable (ISS) with respect to the $\boldsymbol{U}$.
2) The joints' torques peak at $t = D$s and then decline by the decremental tracking errors.
3) The predictor-based controller analytically and experimentally compensates the input delay and achieves the closed-loop stability.

It is worth mentioning that time-varying input delays and model uncertainties were not considered through the predictor-based controller design, which may potentially result in the robot failures; this problem has not yet been addressed. Therefore, we are currently focusing our efforts on designing a nonlinear adaptive time-delay control scheme with application to high-DOF robotic manipulators. This work is part of the first author's Ph.D. dissertation. The AVI files of the experiments are accessible through our Dynamic Systems and Control Laboratory (DSCL) website https://peimannm.sdsu.edu/.

Acknowledgement

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SIUE School of Engineering's Lotfi Leads National Advancement of Mechatronics and Robotics Education

Nima Lotfi, PhD

Mechanical Engineering Department

Southern Illinois University Edwardsville

The National Science Foundation (NSF) has awarded $49,957 to Southern Illinois University Edwardsville in support of School of Engineering's (SOE) Dr. Nima Lotfi's work to advance mechatronics and robotics education by pioneering a more cohesive curricular approach across the nation.

Dr. Lotfi giving the opening remarks at the first FoMRE workshop.

Dr. Lotfi is an assistant professor in the SOE's Department of Mechanical Engineering. As a teacher-scholar in the SOE's mechatronics and robotics engineering (MRE) program, he has witnessed the area of study's dynamic growth and notes the need for collaborative development of educational materials. "We are thrilled about the rapid growth in enrollment we have observed since we started our new mechatronics and robotics engineering program two years ago," said SOE Dean Cem Karacal, PhD. "This new interdisciplinary program is one of the emerging fields in engineering and we are happy to be one of the first in our geographic region to offer it. We are proud to have faculty members like Dr. Nima Lotfi lead the way in this new frontier in engineering education."

Dr. Lotfi is the principal investigator (PI) of the NSF-funded endeavor, titled "Workshops for the Future of Mechatronics and Robotics Education." His co-PI's include Vikram Kapila, PhD (New York University); Mike Gennert, PhD (Worcester Polytechnic Institute); and James Mynderse, PhD (Lawrence Technological University).

Interactive sessions at the first FoMRE workshop

"Mechatronics and robotics engineering professionals are shaping the world by designing smart and autonomous systems, and processes that will improve human life and welfare," Dr. Lotfi said. "MRE requires an interdisciplinary knowledge of mechanical, electrical, computer, software, and systems engineering to oversee the entire design and development process. Our work in MRE education is critical to prepare our students for careers at the human-technology frontier."

The project's main goal is to offer workshops aimed at bringing together MRE educators, students and professionals to share experiences and initiate efforts toward defining the field. The first workshop on the Future of Mechatronics and Robotics Education (FoMRE) was held in September 2018 in conjunction with ASME Dynamic Systems and Control Conference in Atlanta, GA, USA. In this workshop, more than 30 academic and industrial professionals from around the world gathered to discuss the future of MRE and establish a standardized set of educational material, including frameworks, curricula, course outlines, experiments, and assignments to make MRE education more widely available and accessible. Travel support was provided to workshop participants through generous support from NSF and Quanser. "Quanser has been very supportive of our efforts by continuously providing expertise and financial support, so we are extremely grateful to Quanser and NSF in helping us reach our goals."

Project collaborators are also placing emphasis on outreach initiatives that will ensure inclusivity and diversity among workshop participants. Their future work will expand the MRE educational community to incorporate educators in K-12 institutions, potentially reshaping and reinvigorating K-12 STEM education.

"By recruiting the next generation of MRE educators and professionals, we aim to inspire succeeding generations of students to enter engineering with the skills to lead the nation in this emerging field," explained Dr. Lotfi. "The drivers of coming societal employment changes, including machine learning, artificial intelligence and robotics, are significant components of the MRE knowledgebase."

Dr. Lotfi and his collaborators will continue their efforts towards revolutionizing Mechatronics and Robotics Education. Some of their future activities include holding online webinars, outreach programs, and three more workshops at

- International Conference on Robotics & Automation (ICRA 2019), Montreal, May 2019
- American Society for Engineering Education Annual Conference (ASEE 2019) Tampa, June 2019
- Robotics Summit and Expo, Boston, June 2019

Travel support will be available for the participants of these workshops. More information can be found on the community webpage at www.mechatronicseducation.org.

Upcoming Division-Sponsored Conferences

2019 American Control Conference, July 10-12, 2019, Philadelphia, USA

Conference Website
http://acc2019.a2c2.org

Important Dates
January 31 2019: Notification of Acceptance/Rejection
March 15 2019: Final Paper Submission

2019 IEEE/ASME International Conference on Advanced Intelligent Mechatronics
July 8-12, 2019, Hong Kong Science Park, Hong Kong, China

Conference Website
www.aim2019.org.

Important Dates
February 10, 2019: Submission of Special & Invited Session Proposals
February 10, 2019: Submission of Tutorial & Workshop Proposals
February 28, 2019: Submission of Contributed & Invited Papers
April 25, 2019: Notification of Paper Status
May 15, 2019: Final Paper Submission
May 28, 2019: Advanced Registration

See also the 2018 Summer Issue of ASME DSCD Newsletter

The ASME 2019 Dynamic Systems and Control Conference
October 9 – 11, 2019
Grand Summit Hotel, Park City, Utah

Conference Website
https://www.asme.org/events/dscc

Important Dates
April 01 2019: Draft Paper Submission
May 27 2019: Notification of Acceptance/Rejection
May 27 2019: Copyright Process Opens
June 28 2019: Copyright Agreements Completed
July 01 2019: Final Paper Submission

Open positions

Job opening for Assistant Professor, Tenure Track, in Mechanical Engineering at the University of Washington – Robotics and Controls

The Mechanical Engineering Department in the College of Engineering at the University of Washington, Seattle, invites outstanding faculty candidates to apply for multiple full-time tenure-track faculty positions at the assistant professor level. Candidates with a strong background in all areas of robotics and controls are particularly encouraged to apply. The Department seeks to build on its existing strengths in human/robotic interaction, automated assembly, system autonomy, machine learning, digital and additive manufacturing, and prosthetics, but the individual's potential to conduct world-class research and to innovate in robotics and controls is more important than the specific area of specialization. Successful applicants will be expected to leverage the ME Department's and the University's competitive advantage in robotics and controls and to help launch multidisciplinary research efforts.

Additional Description can be found at UW Site:
http://ap.washington.edu/ahr/position-details/?job_id=40505

Application URL:
apply.interfolio.com/57480

Faculty Opening-Design and Manufacturing, Department of Mechanical Engineering, University of Minnesota - Twin Cities

The Department of Mechanical Engineering at the University of Minnesota-Twin Cities invites applications to fill a full-time, tenure-track position broadly defined in the area of Design and Manufacturing, beginning Fall 2019. We encourage applications from individuals with a strong foundation in design, manufacturing, and control. Areas of interest include but are not limited to: sensing and automation, medical devices, biomechanics, and control of mechatronic systems. The appointment is expected to be at the Assistant Professor level, but applicants at all levels will be considered if they have a particularly strong record of research and teaching accomplishments, scientific leadership, and creativity.

Applicants are expected to hold or complete by Fall 2019 a Ph.D. in Mechanical Engineering (or a closely related discipline) and have demonstrated the potential to conduct a vigorous and significant research program as evidenced by their publication record and supporting letters from recognized leaders in the field. The candidate's expertise and documented research activities must demonstrate a strong potential to enhance both the Department's research and teaching missions. Successful candidates are expected to build strong, externally-funded, highly-visible research programs and to become recognized leaders in their field. Information on the current research activities of the department can be found at http://www.me.umn.edu/research/. The ability to effectively teach at both the graduate and undergraduate levels to a diverse group of students is required.

Applications for this position are being accepted online at: https://z.umn.edu/dm18. To assure full consideration, applications should be received by January 1, 2019, but they will continue to be accepted until the position is filled. We particularly welcome applications from candidates from diverse cultures and communities because we believe that diversity helps broaden perspectives and enriches classroom and research experiences within the department and University of Minnesota.

Contacts

New group email of ASME DSCD:
dscd-list@googlegroups.com

List of past discussions:
https://groups.google.com/forum/#!forum/dscd-list.

For more options, visit
https://groups.google.com/d/optout.

The Dynamic Systems and Control Division Newsletter is published twice annually (Summer & Winter) to the Division's email list. Please submit your items for publication by e-mail to the editorial office:

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