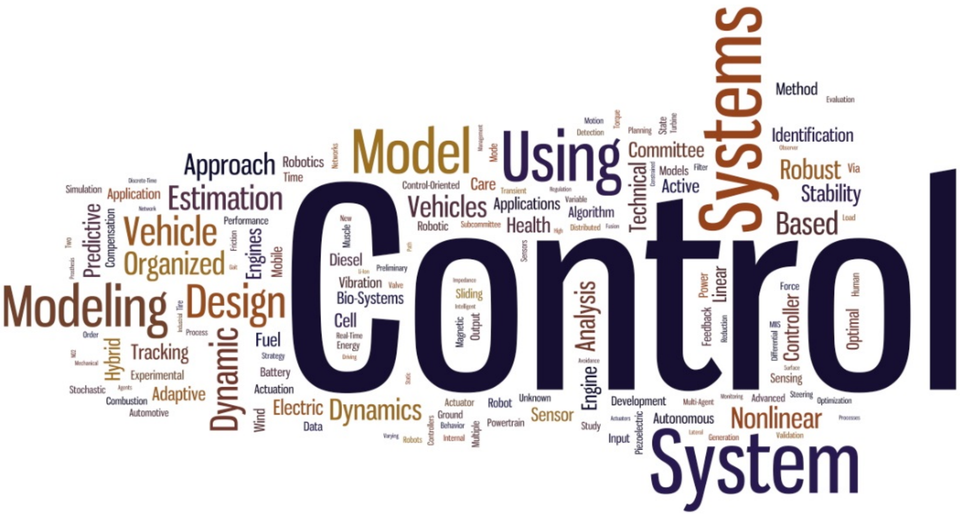


DSCD Newsletter Summer 2017

August 16, 2017

DYNAMIC SYSTEMS AND CONTROL DIVISION NEWSLETTER

IN THIS ISSUE

Editor's Note

Dear colleagues,

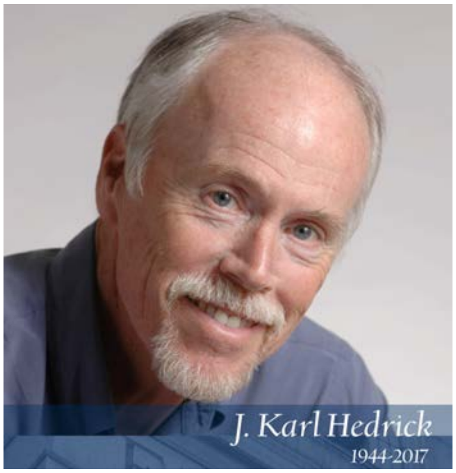
This issue of ASME DSCD Newsletter contains the feature "In Memory of Professor Karl Hedrick" by the controls faculty from the Department of Mechanical Engineering, UC Berkeley, Andrew Alleyne, Joseph Beaman, Dong-il (Dan) Cho, Eduardo Misawa, Rajesh Rajamani, and A.Galip Ulsoy. The feature pays tribute to the life of Professor J. Karl Hedrick (1944-2017), a longtime community member, mentor, and advocate of control engineering. We hope you will be as inspired by his story as we are.

A second feature of this newsletter is "John J. Moskwa (1950 – 2017): Musician, Mechanic, and Engineer" by Eduardo Misawa. Professor Moskwa passed away on June 3 after battling pancreatic and liver cancer. We are sharing to you John's 2015 Newsletter article "Single-Cylinder Engine (SCE) Transient Test System" as a tribute to his individuality and passion for powertrain controls.

In the article "Young Investigators in Dynamic Systems and Controls," we speak with six 2016 awardees of the NSF CAREER award from the Dynamics, Control and Systems Diagnostics (DCSD) Program in the Division of Civil, Mechanical and Manufacturing Innovation (CMMI). In the dialogues, the young investigators shared their engagements with research and education.

We appreciate the great efforts of guest editors Dr. Peter Seiler Jr and Dr. Mahdi Shahbakhti, whose editing and outreach made the first feature possible in its current form. Future newsletters will continue to support special issues, in addition to community news such as call for papers/proposals, conference information, educational activities, introduction of experimental platforms, and job postings. We enthusiastically look forward to your future contributions.

Editor: Xu Chen, University of Connecticut
Associate Editor: Jianguo Zhao, Colorado State University
Guest Editors: Peter Seiler Jr, University of Minnesota, Mahdi Shahbakhti, Michigan Tech. University



Professor Hedrick, 1944-2017

J. Karl Hedrick was best known for the development of nonlinear control theory and its applications to transportation, including automated highway systems, powertrain controls, embedded software design, formation flight of autonomous vehicles, and active suspension systems. Hedrick also made important contributions to nonlinear estimation and control.

Hedrick received his bachelor's degree in engineering mechanics at the University of Michigan in 1966. He earned his master's and his doctoral degrees in aeronautical and astronautical engineering at Stanford University in 1970 and 1971, respectively.

From 1974 to 1988, Hedrick was a professor of mechanical engineering at the Massachusetts Institute of Technology, where he directed the Vehicle Dynamics Laboratory. He then joined the Department of Mechanical Engineering at the University of California, Berkeley in 1988, where he taught graduate and undergraduate courses in automatic control theory.

While at Berkeley, Hedrick served as the chair of the Department of Mechanical Engineering (1999–2004), the James Marshall Wells Academic Chair (since 1997), and as director of the university's Partners for Advanced Transit and Highways Research Center (1997– 2003), which conducts research in advanced vehicle control systems, advanced traffic management and information systems, and technology leading to an automated highway system. He was also the director of Berkeley's Vehicle Dynamics Laboratory, as well as a codirector of the Hyundai Center of Excellence in Active Safety and Autonomous Systems.

Hedrick was a member of the National Academy of Engineering, the Society of Automotive Engineers, and the American Institute of Aeronautics and Astronautics. He was also a fellow of the American Society of Mechanical Engineers (ASME), and past chair of the Dynamic Systems and Control Division and its Honors Committee.

Other honors include the Outstanding Paper Award from the Institute of Electrical and Electronics Engineers, 1998; the American Automatic Control Council's O. Hugo Schuck Best Paper Award, 2003; the ASME Division of Dynamic Systems, Measurement, and Control's Outstanding Investigator Award, 2002; and the ASME Journal of Dynamic Systems, Measurement, and Control Best Paper award in 1983 and 2001. Hedrick received ASME's 2006 Rufus Oldenburger Medal, which recognizes significant contributions and outstanding achievements in the field of automatic control. He delivered the ASME Nyquist Lecture in 2009.

He has written two books and published more than 140 peer-reviewed archival publications. Spanning his career at Arizona State, MIT and Berkeley, Hedrick has graduated over 70 Ph.D. students.

Contributed by the Department of
Mechanical Engineering
University of California, Berkeley

Celebration of the Life of J. Karl Hedrick

Francesco Borrelli, UC Berkeley

On May 6th 2017, the UC Berkeley Mechanical Engineering department and the College of Engineering organized a memorial service for Professor J. Karl Hedrick. It was an event to celebrate Karl's professional and private life. It was a very beautiful and touching ceremony with hundreds of participants. I had the honor to start the event and introduce the speakers. I am copying below some excerpts from my speech.

Good afternoon everybody. On behalf of the mechanical engineering department, the college of engineering and UC Berkeley, welcome and thank you so much for being here today. Your presence here means a lot to all of us.

Many of you have traveled from very far, canceling important work and family commitments, to be here. We want you to know that we really appreciate your effort.

Two months ago on Feb 22nd, Professor Karl Hedrick passed away. A year before that he was diagnosed with lung cancer. We knew this moment would be coming. However, we all thought we had more time with him. For all of us it was just too quick, unexpected.

Today we are here to remember him, to share our memories with his friends and colleagues and especially with his family.

Colleagues, friends, and collaborators from Berkeley, his former students, industrial and academic collaborators will soon come to the podium and share some thoughts and memories of Karl.

I think it is a very important moment for all of us, especially in our super busy, hyper connected lives. So please turn off your phone and use this time to listen and remember.

I will start with telling you about Karl first, his main accomplishment and my memories.

Professor Hedrick received his bachelor's degree in engineering mechanics at the University of Michigan in 1966. He earned his master's and his doctoral degrees in aeronautical and astronautical engineering at Stanford University. He started his academic career as an assistant professor at the Aerospace Engineering Department of Arizona State University. From 1974 to 1988, Hedrick was a professor of mechanical engineering at the Massachusetts Institute of Technology, where he directed the Vehicle Dynamics Laboratory. He then joined the Department of Mechanical Engineering at the University of California, Berkeley in 1988.

I still remember him telling me his story of Tomi calling him from Berkeley and asking him if he had any good students….and him replying… "what about me"? He had enough of the cold weather of Boston and was ready for a better place.

Over the years he became one world expert of nonlinear control theory and its applications to transportation, including automated highway systems, powertrain controls, formation flight, autonomous vehicles, and vehicle dynamics.

While at Berkeley, Hedrick served as the chair of the Department of Mechanical Engineering (1999–2004), Director of a center called PATH (Partners for Advanced Transit and Highways Research Center) (1997–2003). Probably his most know work at PATH was the autonomous platoon study, which culminated in the famous highway demonstration in 1997 – a team effort which involves Professor Tomizuka, Professor Varaya, and a number of PATH researchers including Dr. Wei Bin, Professor Rajamai, and Dr. Shaldover.

Professor Hedrick's list of honors and award is incredibility long. Hedrick was a member of the National Academy of Engineering, the Society of Automotive Engineers, and the American Institute of Aeronautics and Astronautics. He was also a fellow of the American Society of Mechanical Engineers (ASME), and past chair of the Dynamic Systems and Control Division and its Honors Committee. He won all best paper awards and the Rufus Oldenburger Medal, which recognizes significant contributions and outstanding achievements in the field of automatic control.

Spanning his career at Arizona State, MIT and Berkeley, Hedrick has graduated over 70 Ph.D. students. All of them very successful in industry and academia, and many of them are here today with us.

My name is Francesco Borrelli. I am a professor in the Mechanical Engineering Department. I met Karl roughly 10 year ago, when I joined Berkeley as an assistant professor. And yes, first it is true he was super smart and knowledgeable. But in addition, what really struck me was how human and kind he was. He was a real gentleman… and it was so natural for him.

Karl was always cheerful, encouraging, caring, and as for many in this room he strongly impacted my life. Professionally he gave me the opportunity to work with a number of company on very interesting projects. But most of all he taught (or at least tried to teach) me how to cope with stress, be calmer and still get lots of things done.

He was my low pass filter and it was very difficult to make him angry. I still remember his face, after we returned from a trip to Korea which lasted less than 24 hours (which was my idea). Ohhh we were so tired. He looked at me angry "I should have never listened to you" he said. Then he paused, smiled and said "Francesco!".

Our first research proposal was ten year ago. Our last one was approved a few weeks ago. We have lost only a few of them. Six years ago we wrote a really successful one and built what is known as the Hyundai Center of Excellence at UC Berkeley on active safety systems. Karl has probably collaborated with all automotive companies during his career. However, the experience over the past six years has been unique. We have been fortunate enough to attract the interest of the Hyundai Automotive Company's top management and build what it is probably the biggest collaboration between an automotive company and a university in the USA. A collaboration, which encompasses fundamental research, experimentation and training, the Hyundai Center of Excellence really strengthen my collaboration with Karl. We were doing research, traveling, and preparing courses together. I have beautiful memories of our trip to Korea where he was always welcomed as a king.

I do not know if you know this, but six of Karl's formal students are now professors in top Korean universities.

Outside work, first and foremost his family. He has a beautiful family and in the past years he has been very excited about the weddings and grandchildren. After family, there was tennis. You probably know that he played against top raked players but you might not know that he chaired a committee in the International Tennis Federation whose task was to regulate technologies (like sensors and data acquisition) in tennis racquets. Today's regulations have been strongly influenced by Karl. After tennis, long bike rides with his wife and family in Europe and after that …… white wine.

Karl Hedrick (front left), Francesco Borrelli (front right), and Berkeley's Hyundai Center of Excellence Program

It has been an honor for me and I consider myself very fortunate to have shared part of my life with him. I miss him very much.

J. Karl Hedrick: The Teacher who became a Friend

Andrew Alleyne, University of Illinois, Urbana-Champaign

It is bittersweet that I am here today gathered with family, friends, and colleagues. On the one hand, I am happy to celebrate Karl's life. On the other hand, my heart is still heavy that we did not have more time with him.

Many things can be said about Karl. That he was a wonderful scholar, that he was an adept administrator, that he was an even keeled leader. These are all true but they won't be what I return to when thoughts of Karl enter my mind. I will always remember him as the teacher who became a friend.

Karl was a teacher; a teacher of life. Not so much by what he wrote on a blackboard or sent in an email. He taught me by example. As I watched him for 25 years, there are several key takeaways that shaped how I approached my own life. Here are some of the best lessons I learned.

First, life is short. Have fun doing what you're doing. Karl had a great way of maintaining a certain levity and sense of humor even when dealing with detailed technical material. It was subtle but the longer one observed him, the more one could see that there was a balance there. The first time I realized our paths would be intertwined was when he made a subtly ribald joke during a class my first semester in graduate school. Few, if any others, in the class got it; they were too busy writing down notes. However, I realized that this is someone that I could work with. Someone who can work hard but still enjoy themselves along the way. That outlook has stayed with me to this day.

A corollary to this lesson is that there are few problems in life that don't look smaller over a good glass of Chardonnay.

Second, get your priorities in order and keep the family first. When I first met him, he made sure that he went home at 4:30 or 5 pm to coach his kids in sports. He was rarely, if ever, in the office on weekends. He demonstrated that one can be involved with life at home and still excel at work. I can't tell you how much I respected that. I've been trying to live that lesson for the past 20 years; probably not as well as Karl.

Third, take care of people…or at the least, don't be a jerk. Many would say Karl was a great man; I can say Karl was truly a "good guy." The kind of guy you would like to keep company with. Rarely would he speak ill of others and I cannot remember anyone speaking ill of him. Last year we had a life celebration and dozens of his former students came from far and wide to let him know how much he meant to them. This was a clear testament to his treatment of the people he worked with.

There are other life lessons I've learned but I wish to talk about Karl the friend. Not everyone gets to call their advisor a friend. Over the past 15 years, as my own career has grown, I'd found myself spending time with Karl at meetings and conferences and sharing many things from our lives that had little to do with the subject matter of the meetings: family, health, finance….keeping strange boys away from your daughters. We made a point of finding time for just the two of us a couple of times per year. I will treasure those dinners and late night chats around some bar.

Winston Churchill once said, "We make a living by what we get, we make a life by what we give." Karl gave me a lot over the past 2 decades. As a friend, he gave me an ear to talk to and a brain to pick which

Hedrick with his students and colleagues, Berkeley, California, 06/06/2016 was important when I was determining some of my own life choices. Even though he is no longer with us, memories of him still give me guidance. He is still teaching. I am grateful to have had him as a teacher and more grateful to have counted him as a friend.

Memories of Karl Hedrick

Rajesh Rajamani, University of Minnesota

I was fortunate to be advised by Karl Hedrick for my MS and PhD degrees during 1989-1993. This early influence had a strong impact on my research career. Some of the lessons I learned from him include respect for other disciplines and multi-disciplinary work, the importance of doing rigorous experimental evaluations, and being friendly and generous towards graduate students.

I remember Karl used to invite us occasionally for a lab party at his home in Walnut Creek. We played tennis and did swimming while at his home. At one such party, he was joking with us saying, "Anybody here who wants to graduate needs to beat me at tennis." Several lab members had clever repartees, such as "Why didn't you tell us this earlier? I would have at least gone to the tennis courts everyday instead of coming to the research lab!"

Karl had a significant impact on my professional career. After obtaining my PhD from Berkeley, I was working as a Research Engineer at United Technologies Research Center at East Hartford in Connecticut. He called me one day and asked me if I was interested in coming back to Berkeley to work on an important automated highway systems (AHS) demonstration. I went back to Berkeley, led the longitudinal systems team for the 1997 National AHS Consortium Demonstration in San Diego, and ended up eventually becoming a Professor. I definitely owe my switching of careers from the industrial to the academic track to Karl.

In summary, I feel happy and proud about having worked with Karl Hedrick as his advisee. His lab at Berkeley was a happy place, and to this day I strive to emulate that lab and create a similar atmosphere for my own research group.

A Short Haiku in Memory of Karl Hedrick

A.Galip Ulsoy, University of Michigan

Karl elevated our world:
Tennis, teaching, driverless car
May he rest in peace

Karl's Memorial

Roberto Horowitz, UC Berkeley

Karl was a truly beloved and respected member of our Department, and he will be sorely missed. Karl became a member of our department in 1988 when Tomi, Dave Auslander and I were lucky enough to recruit him from MIT. His positive impact to our department and the University was immediate and long lasting. Up to his untimely death, he was one of the pillars on which our world-renowned program in dynamic systems and control and vehicle dynamics and automation rested.

Teaching Mentor:

Karl was a devoted teacher, who taught extremely popular courses in nonlinear control and vehicle dynamics, and was a beloved advisor and mentor to many students and colleagues. He graduated over 70 Ph.D. students and many of them are well-known leaders in academia and industry – some of them will be speaking later at this event.

ITS:

Karl also had a profound impact in several of our University's research programs, particularly in the field of Intelligent Vehicles and Highway Systems, and I was asked by Alex Bayen, the current director of Institute of Transportation Studies, to say a few remarks regarding Karl's contributions.

AHS: Karl was one of the architects of the world-renowned Automated Highway Systems research program that PATH spearheaded starting in the late 80's. His research contributions in developing longitudinal controllers for vehicle platoons of automated vehicles are still highly relevant to today's autonomous vehicles and were critical to the automated vehicle demonstrations that took place under the AHS program.

PATH Director: Karl later served as the director of the Partners for Advanced Transportation and Highways (PATH) program during the time when AHS funding was being severely curtailed. Despite the cuts, he maintained the strength of the by steering it into exciting new directions.

Chair and Budget:

Karl served our department and the campus in an admirable manner. He was the Chair of the mechanical engineering department, while simultaneously serving as PATH director, a feat that is for me impossible to phantom – now that I'm currently chair after being PATH director. He was also a long-serving member of the campus budget committee, which is the most important committee on the campus and is charged with reviewing all academic merit and promotion cases as well as recommending salary increases.

More recently, Karl, together with Francesco Borrelli, created the Hyundai Center of Excellence, which is among the premier academic research centers in the country that are dedicated to vehicle dynamics, control and autonomy.

Personal:

Karl was among the selected group of people that had a "magical touch" and could affect people in a very positive manner, even unintentionally. Let me finish by recalling an instance in which he positively and profoundly affected me.

As Department Chair, Karl appointed me Vice Chair of Graduate Studies and gave me the opportunity to learn how to do academic administration, under his competent and efficient tutelage. More importantly, he also hired Donna Craig as the head of the department's student services office and this is how Donna and I met. Donna and I have been happily married for several years.

Thank you, Karl!

Karl's Memorial

Masayoshi Tomizuka, UC Berkeley

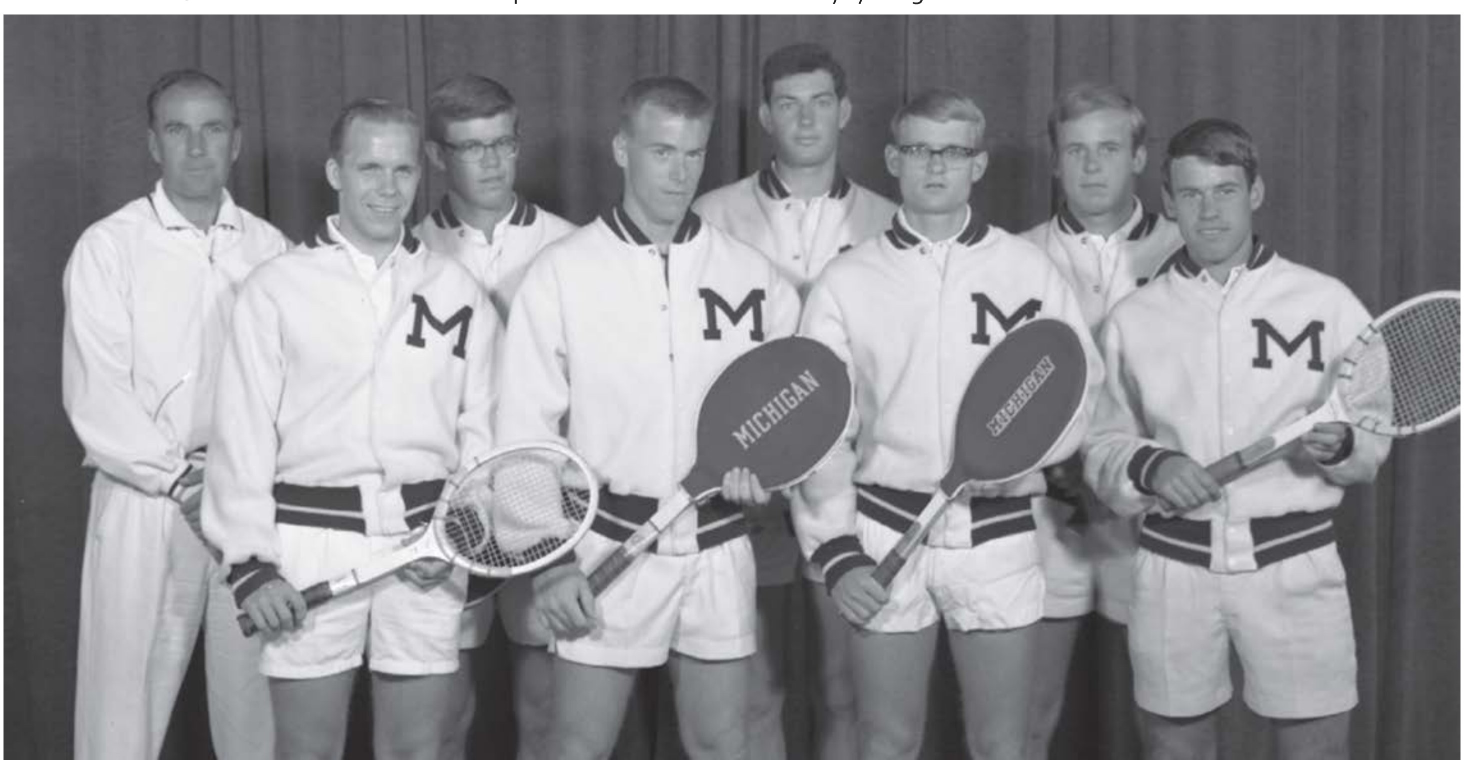
In the fall semester of 1986, I was asked to chair the faculty search committee in the area of controls. At that time, we had a small but extremely popular control program, with Roberto Horowitz, Dave Auslander, and I each supervising 15 to 20 research students.

The department program was known for having strong components in both theory and application, and we were seeking someone with similar strengths. At the time, Karl was a full professor at MIT, and was known for his outstanding contributions to nonlinear control theory and its application to vehicles. Karl and I knew each other well by then. We originally got to know each other shortly after he joined MIT and I joined Berkeley in 1974. When we launched into the faculty search in 1986, he was the ideal candidate for the position, and luckily I was able to convince Karl to apply for the open faculty position.

Fortunately for all of us, Karl joined us in 1988. He built a strong and visible research program of his own quickly. As it turned out, hiring Karl did not solve our problem of having too many research students in our department for the number of faculty we had in the area of controls. We ended up with attracting an even larger number of research students!

When Karl joined us, UC Berkeley was starting a program on highway automation called PATH, Program on Advanced Transit and Highway. Karl and I were charter members of PATH. On automated highways, vehicles must be automatically controlled in two directions: first, in a longitudinal direction to allow vehicles to be close to the car in front of it so that they can "car platoon," we like to say; and second, in a lateral direction to keep vehicles inside their lanes on highways and also to allow them to switch lanes. Karl worked on the longitudinal control piece and I worked on the lateral control piece. This arrangement worked very nicely for both of us. We jointly organized workshops, presented a review paper on vehicle controls for automated highway systems, and had opportunities to travel together to attend conferences and visit automotive companies.

In age and in seniority, Karl and I were close to each other. When he joined the department in 1988, we were both full professors but still relatively young. It was my good fortune to have a wonderful colleague like Karl to grow older with – personally, academically and professionally. Thank you, Karl, for stimulating and inspiring me over the years. I miss you very much, but I will always remember you, our friendship, and the important contributions that you made to UC Berkeley and to our profession.



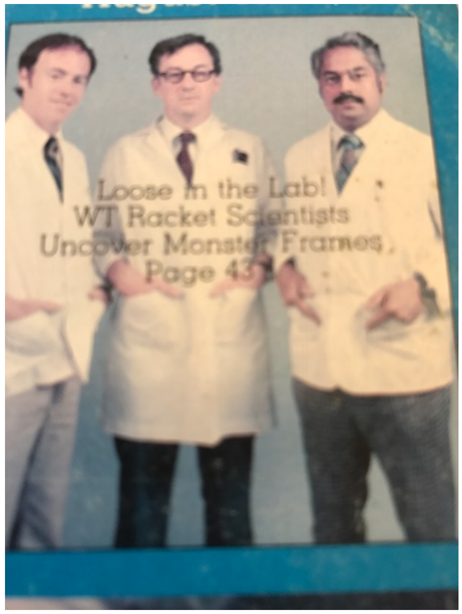
Hedrick and his Michigan tennis teammates

Remembering Karl Hedrick from MIT Days

Joseph Beaman, Dong-il "Dan" Cho and Eduardo Misawa

Karl was a young professor – only 3 years after his Ph.D. – when he joined MIT in 1974. By the time I got to know him in 1983, he was well-established and internationally well-known for his work in nonlinear system analysis, control and estimation, as well as vehicle dynamics and control. Among all graduate students, he was very well respected as the expert in those scientific and technical areas. He was always an easily-approachable professor, great mentor, and thesis advisor. He had an amazing skill to explain the most difficult concepts in very accessible ways. As such, the courses that he taught were always full. I (Eduardo) remember it well because I was the teaching assistant for graduate level systems and controls courses that he regularly taught both in the MIT's graduate program as well as summer extension courses for industrial practitioners. In the same way, he was a graduate advisor for a large number of students in his Vehicle Dynamics Laboratory (VDL) for whom he became a life-long mentor and a friend.

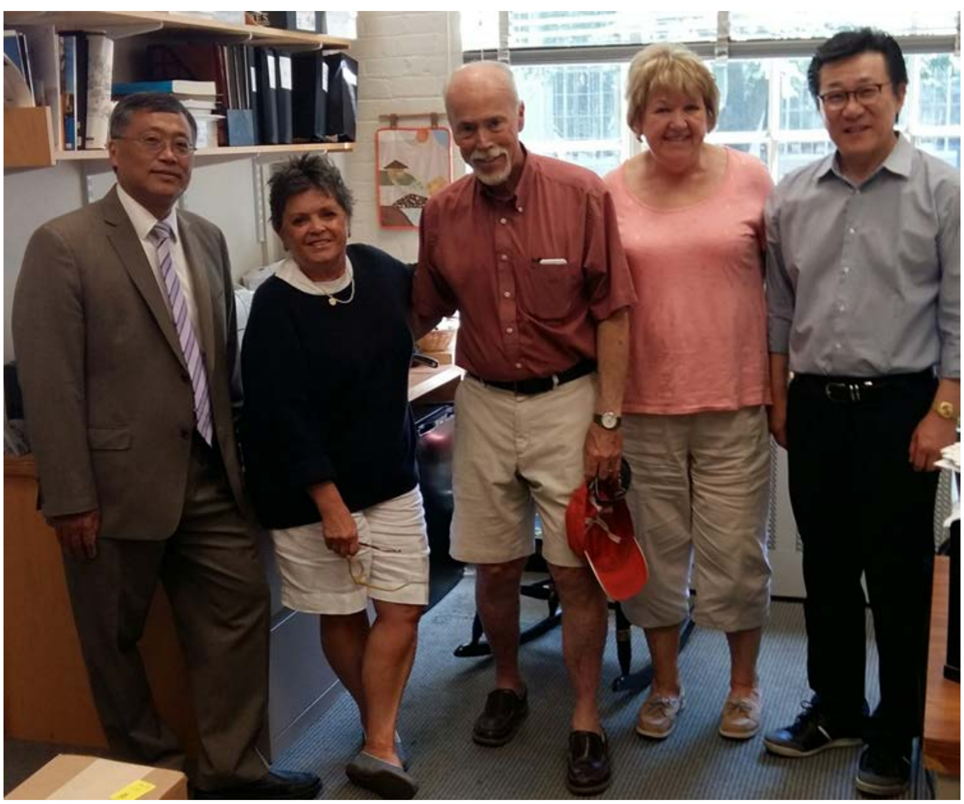
And he has been known at MIT among his colleagues as "an all-around great person" and according to Leslie Regan at MIT: "a fabulous teacher and mentor to all."



Cover of World Tennis Magazine (1981); Courtesy of Leslie Regan

Karl was also known as a top-notch athlete, and he had a parallel research and consultant activity with tennis magazines and with international tennis association. At MIT he was one of the "rocket scientists" involved in testing and researching tennis rackets. His life-long interest and dedication for sports led him to continue to play tennis competitively in the masters age group. Karl was well-known to be a family person involved in tutoring his daughters and coaching tennis and soccer. His family was his highest priority.

For all his students, he passed his passion for application-driven rigorous research and his candor to be a mentor and a genuine human being, features that we all inherited from him. For us, it gives a special meaning to "academic siblings".



Karl Hedrick's last visit to MIT (from left to right: Eduardo Misawa, Leslie Regan, Karl Hedrick, Joan Kravit and Dong-il "Dan" Cho); photo credit: Dong-il "Dan" Cho

John J. Moskwa (January 20, 1950 – June 3,2017): Musician, Mechanic, and Engineer

Eduardo Misawa

Professor John J. Moskwa peacefully passed away surrounded by his family and friends on June 3, 2017 after battling pancreatic and liver cancer. He is survived by his two children, Joe and Susan Moskwa, and his wife Arlinda Michael.

He was an accomplished musician who began his musical studies with piano and trumpet. He studied and performed music seriously throughout high school and at Wayne State University and the Cleveland Institute of Music, where he was a Principal Trumpet. He taught and played at the University of Guadalajara and played Principal Trumpet with the Symphony Orchestra of the Northwest (Mexico). After his return to US he played with the Detroit Symphony Orchestra and then with the Bloomington Symphony in Minnesota.

Dr. Moskwa started his professional mechanical career as a diesel mechanic with the City of Detroit's Department of Transportation in 1974. This job developed his interest in engineering, leading to studies at Henry Ford Community College, the University of Michigan, a Ph.D. from MIT and a professorship at the University of Wisconsin-Madison. After receiving his BSE and MSE degrees from the University of Michigan, he joined Cummins Engine Co. in 1981 in the Experimental Mechanics Laboratory. Later while working toward his Ph.D. under Professor Karl Hedrick at MIT, he worked at General Motors Research Laboratories in Power Systems Research.

Dr. Moskwa started working at the University of Wisconsin-Madison in 1988 as an Assistant Professor of Mechanical Engineering. During his 28-year career at the University he developed and taught courses in dynamic systems and control, thermodynamics, vehicle dynamics and design, powertrain systems and hybrid vehicles. He started and directed the Powertrain Control Research Laboratory, and he was also the founding faculty advisor for the College of Engineering's Hybrid Electric Vehicle program. He published over 80 peer-reviewed publications, over 30 internal technical reports for various companies and held 5 US patents. He mentored over 45 Master's and/or Ph.D. students. He was also the President of Powertrain Consultation & Research, LLC, an engineering consulting company. His engineering and teaching contributions have been well recognized: he was a fellow of ASME and SAE, and recipient of ASME's Charles Stark Draper Innovative Practice Award, SAE's Edward N. Cole Award for Automotive Engineering Innovation, International Council for Powertrain Engineering and Management 's Powertrain Excellence Awards, and SAE's Ralph R. Teetor Educational Award, among many other awards.

Dr. Moskwa retired from the University in January 2016. He continued to enjoy music and regularly attended concerts of major symphonic orchestras, while continuing with engineering consulting activity. On June 3, 2017, our community lost an outstanding colleague and dear friend. We will miss him.

Single-Cylinder Engine (SCE) Transient Test System

John J. Moskwa, Mechanical Engineering Department, University of Wisconsin-Madison

(Re-sharing John's 2015 Newsletter article)

Researchers in the Powertrain Control Research Laboratory (PCRL) at the University of Wisconsin-Madison have, for over 10 years, been developing transient test systems for single-cylinder research engines (SCE) that replicate the dynamics of a multi-cylinder engine (MCE). This is accomplished by replicating the cylinder instantaneous boundary conditions that exist in the MCE. This article is a brief overview of the lab's most recent system and developments.

The Problem Being Addressed: Most automotive engines used in vehicles are MCEs, but SCEs are still used extensively in engine research and sparingly in engine development. MCEs and SCEs operate very differently in terms of rotational dynamics, heat transfer, and gas dynamics both outside and inside the cylinder, as well as other dynamic properties. Hence, findings from the use of SCEs are not representative of what occurs in MCEs. Also, typical SCE setups used in most research centers have not differed substantially from what was used 50+ years ago, with very little thought given to the actual dynamic operation of the engine, although there are exceptions I have seen used by formula 1 race teams.

PCRL's SCE Transient Test Systems: Researchers at PCRL have designed, built, tested, and patented variations of a transient test system for SCEs that replicate the instantaneous dynamic performance of MCEs. While additional subsystems are under consideration, I discuss three subsystems that have been developed for rotational dynamics, intake gas

Figure 1. SCE transient test system that simulates MCE dynamic performance

dynamics, and cylinder heat transfer dynamics. The entire transient test system is shown in Figure 1.

The SCE rotational dynamics simulator [4, 5] replicates the instantaneous crankshaft rotational velocity throughout the engine cycle that would exist in a MCE. This is accomplished through the use of a hardware-in-the-loop (HIL) system that is the synthesis of a real-time dynamic engine model and a low inertia transient dynamometer. The engine model simulates the dynamics of the missing or virtual cylinders of a MCE, and includes the slider crank geometry and dynamics of each cylinder, as well as combustion, heat transfer, friction and related sub-models to simulate the torques that are imposed on the crankshaft by each cylinder. When put together, these sub-models simulate the instantaneous torque profile throughout the cycle that would be imposed on a cylinder within the MCE. The torque data is then applied to the SCE by means of a transient dynamometer system, resulting in the engine speed trajectory throughout the cycle that exists in the MCE. Currently, a hydrostatic dynamometer is designed and built in PCRL, but a high-quality low-inertia transient electric dynamometer system could also be used for this application. The result is a virtual engine dynamic simulator. Examples of engine speed experiment data profiles are shown in Figure 2.

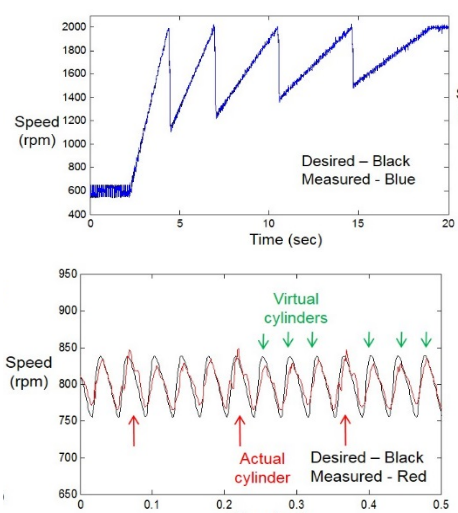


Figure 2. Typical experimental data from the SCE transient test running through gears (1→5 upshifts).

The SCE intake gas dynamics simulator [6] replicates the instantaneous gas intake dynamics throughout the engine cycle that would exist in a MCE. This is accomplished by means of a double-walled chamber where the inner space is the intake plenum and the outer space is a vacuum. These two spaces are separated by means of a number of high speed pneumatic valves that control the flow of gas out of the plenum representing the flow that would go to the other runners of a MCE intake manifold. The valves are dynamically controlled to control the plenum pressure profile in the MCE. This profile can be established by means of another HIL system representing the MCE intake system, or it can be imposed from data collected from a MCE test. Either way, a control system monitors this instantaneous pressure and carefully controls it. The runner connection between the plenum and the intake valve is identical to the runner geometry and length of the MCE. The resulting gas flow through the intake valve is now identical to the MCE, due to the exact runner geometry for Helmholtz resonances, and careful control of the plenum pressure trajectory.

The intake air simulator (IAS) concept is shown in Figure 3, and representative experimental data are shown in Figure 4.

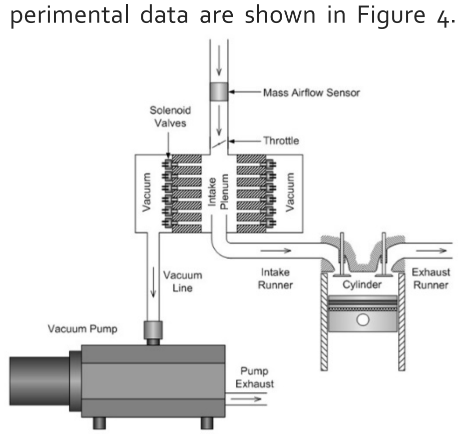


Figure 3. Intake Air Simulator (IAS) concept

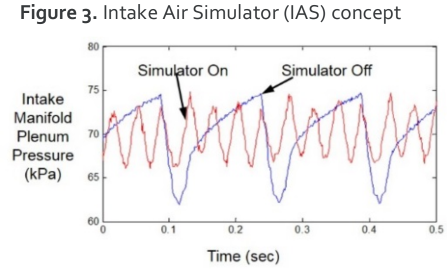


Figure 4. Comparison of experimental engine data with the IAS turned off and on

Since the design of the original IAS, there have been two upgrades to address deficiencies. IAS2 [7] uses a combination of proportional and poppet valves to decrease the required number valves and reduce the complexity of the control system and hardware. A variation also uses a combination of vacuum and pressure chambers (also an option in the original IAS) to improve desired pressure profile tracking. IAS3 uses a combination of proportional and rotary valves to further simplify the control strategy and significantly increase the maximum engine speed where this system can be used. IAS3 has been simulated to 15,000 rpm with reasonably accurate results [8].

The SCE cylinder heat transfer dynamics simulator [9] replicates the cylinder liner temperature and heat transfer profiles circumferentially around the cylinder that exists in a target cylinder within a MCE. As mentioned earlier, the cylinder sleeve temperature varies circumferentially around each cylinder and the temperature profiles vary from cylinder to cylinder. Figure 5 shows typical liner temperature distributions for one bank of a V-6 engine with crossflow coolant.

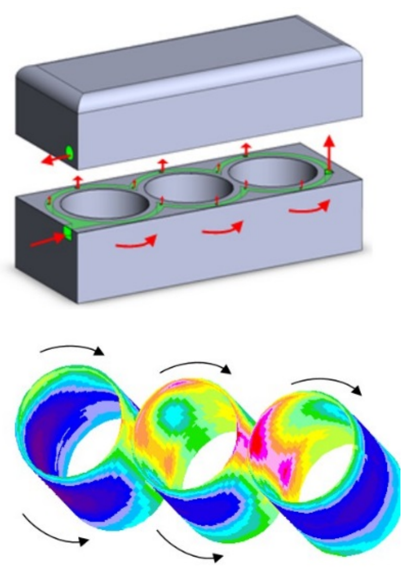


Figure 5. Typical cylinder liner temperature variation in one bank of a V-6 engine with crossflow coolant (red=hotter, blue=cooler)

The temperatures and heat transfer around the cylinder liner is controlled by means of 6 independent coolant passages. In the original heat transfer system (HTS) both the temperature and flow rates in each passage or zone were controlled independently of the other

Figure 6. Cylinder block construction showing the 6 coolant passages surrounding the liner to control temperature and heat transfer

passages or zones. This allows the temperature profiles around the circumference of the liner to be controlled. A seventh zone is in the cylinder head, which can also be independently controlled. The construction of the cylinder block is shown in Figure 6.

A new version of the heat transfer system (HTS2) shown in Figure 1 [10] has been designed and built. This system uses a common controlled coolant temperature for all zones and controls each zone temperature independently through variations in coolant flow. This new approach significantly simplifies the control strategy of the system, and results in better temperature control, in addition to overcoming several practical implementation problems that arose with the original system.

The complete SCE transient test system presented in Figure 1 can represent a virtual MCE or a virtual powertrain, as shown in the experimental data in Figure 2 accelerating through the gears. This system is capable of performing a number of dynamic engine tests that are currently not possible with typical SCE test stands. These tests include transient cold start, FTP or other emission test procedures, exploring correlations between cylinder liner temperatures and emissions, effects of powertrain design or transmission control strategies on engine emissions, any rapid transient test with slew rates to 10,000 rpm/sec, etc.

The author would like to thank both GM Powertrain and Ford Motor Company for their support of this program, as well as the many students that made useful contributions to the transient test system program.

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Young Investigators in Dynamic Systems and Controls

In this article, we speak with six awardees of the 2016 Faculty Early Career Development (CAREER) award from the National Science Foundation (NSF). The CAREER Program is "a Foundation-wide activity that offers the National Science Foundation's most prestigious awards in support of early-career faculty who have the potential to serve as academic role models in research and education and to lead advances in the mission of their department or organization." Our six guests received the award from the Dynamics, Control and Systems Diagnostics Program in the Division of Civil, Mechanical and Manufacturing Innovation (CMMI). In our dialogues with them, we asked about the general scopes of their research, their engagement with, and vision of, the fields, and their related educational practice.

Dr. Zheng Chen is currently a Bill D. Cook Assistant Professor in Mechanical Engineering at the University of Houston and directs the Bio-inspired Robotics and Controls Lab there. Dr. Chen received his PhD degree from Michigan State University (MSU) in 2009. His Ph.D. dissertation at MSU exploited a control systems perspective to examine ionic polymer-metal composite artificial muscles and sensors. That work produced a number of highly cited publications and a US patent. Dr. Chen was a postdoc with University of Virginia, an R&D engineer with Baker Hughes, and then an assistant professor with Wichita State University prior to joining the University of Houston in 2017. Dr. Chen's research interests are focused on bio-inspired robotics, smart material artificial muscles and sensors, renewable energy systems, dynamic systems and controls.

Dr. ShiNung Ching is currently the Das Family Career Development Assistant Professor in the Preston M. Green Department of Electrical and Systems Engineering at Washington University in St. Louis. He holds secondary appointments in the Department of Biomedical Engineering and the Division of Biology and Biomedical Science. Dr. Ching received his B.Eng (Hons.), M.A.Sc., and Ph.D., degrees from McGill University in 2003, the University of Toronto in 2005, and the University of Michigan in 2009, respectively. He was subsequently a postdoctoral associate at the Massachusetts Institute of Technology and the Harvard Medical School from 2009-2013. Dr. Ching's research interests are in the intersection of systems and control theory, theoretical neuroscience and neural engineering. He is author of over 60 refereed papers and the textbook "Quasilinear Control".

Dr. Robert D. Gregg IV received the B.S. degree in Electrical Engineering and Computer Sciences from the University of California, Berkeley in 2006 and the M.S. and Ph.D. degrees in Electrical and Computer Engineering from the University of Illinois at Urbana-Champaign in 2007 and 2010, respectively. He joined the Departments of Bioengineering and Mechanical Engineering at the University of Texas at Dallas as an Assistant Professor in June 2013 with an adjunct appointment at the UT Southwestern Medical Center. Prior to joining UT Dallas, he was a Research Scientist at the Rehabilitation Institute of Chicago and a Postdoctoral Fellow at Northwestern University. Dr. Gregg has over 50 peer-reviewed publications and 5 patent applications on the design and control of legged robots, powered prosthetic legs, and exoskeletons. He is a recipient of the NSF CAREER Award, the NIH Director's New Innovator Award, and the Career Award at the Scientific Interface from the Burroughs Welcome Fund. His work has been recognized with the Best Student Paper Award of the 2008 American Control Conference and the 2015 IEEE Conference on Decision & Control, the Best Technical Paper Award of the 2011 CLAWAR Conference, and the 2009 O. Hugo Schuck Award from the IFAC American Automatic Control Council.

Dr. Ross L. Hatton is an Assistant Professor of Robotics and Mechanical Engineering at Oregon State University, where he directs the Laboratory for Robotics and Applied Mechanics. He received PhD and MS degrees in Mechanical Engineering from Carnegie Mellon University, following an SB in the same from Massachusetts Institute of Technology. His research focuses on understanding the fundamental mechanics of locomotion and sensory perception, making advances in mathematical theory accessible to an engineering audience, and on finding abstractions that facilitate human control of unconventional locomotors. Hatton's group also works with local industry to transfer modern developments in robotics from the lab to the factory.

Dr. Hae Young Noh is an assistant professor in the Department of Civil and Environmental Engineering and a courtesy assistant professor in the Electrical and Computer Engineering at Carnegie Mellon University. Her research interest is in indirect sensing to infer information about dynamic systems using statistical signal processing and machine learning techniques, particularly algorithm development for smart structures and systems to conserve energy and resources, provide safe, functional, and sustainable environments, and improve people's quality of life. Her current research projects include vehicle-based infrastructure monitoring and building vibration based human and environment sensing. She received her Ph.D. and M.S. degrees in the Civil and Environmental Engineering department and the second M.S. degree in Electrical Engineering at Stanford University. She studied Mechanical and Aerospace Engineering at Cornell University as an undergraduate. She received the Google Faculty Research Award in 2013 and 2016, and the National Science Foundation CAREER award in 2017.

Dr. Simona Onori received her Laurea Degree, summa cum laude, (Computer Engineering) in 2003, her M.S. (ECE) in 2004, her Ph.D. (Control Engineering) in 2007, from University of Rome 'Tor Vergata', University of New Mexico, Albuquerque, USA, and University of Rome 'Tor Vergata', respectively. She has been an Assistant Professor at Clemson University International Center for Automotive Research (CU-ICAR) since August 2013, where she also holds a joint apportionment with the Electrical and Computer Engineering. She holds visiting professor positions at University of Trento, Italy (2014), Beijing Institute of Technology, China (2015), University of Orleans, France (2016).

Prior to joining the CU-ICAR faculty, Dr. Onori was a research scientist and lecturer at the Ohio State University. Her background is in control system theory and her current research focuses on control application with emphasis on ground vehicle propulsion systems, including electric and hybrid-electric drivetrains, aftertreatment and electrochemical energy storage systems, and waste heat recovery systems. Her research is currently funded by GM, Fiat Chrysler Automobile, Borg Warner, US Army and NSF. She has co-authored a book on Energy Management Strategies for HEVs, two-book chapters and more than 70 peer-reviewed papers in journals and conferences. She serves as chair of the IEEE CSS Technical Committee of Automotive Controls, and vice-chair of IFAC Technical Committee of Automotive Control, and she is a member of IEEE, ASME, SAE, IFAC and various technical committees. She has served in the IEEE CSS and ASME DSCD Conference Editorial Board since 2014 and 2012, respectively, and she is Senior Member of IEEE.

She is the recipient of the 2017 NSF CAREER Award, the 2017-2019 College of Engineering and Science Dean's Faculty Fellow Award, Clemson University, the 2017 Esin Gulari Leadership & Service Award in the College of Engineering, Computing and Applied Sciences, Clemson University, 2016 Energy Leadership Award in the category Emerging Leader (for the Carolinas), the 2015 InnoVision Award (South Carolina), 2012 Lumley Interdisciplinary Research Award by OSU College of Engineering and the TechColumbus 2011 Outstanding Technology Team Award.

Xu Chen

Q&A with Dr. Zheng Chen about his research titled "CAREER: Artificial Muscle Based on Dielectric Elastomers for Dexterous and Compliant Prostheses"

Q. Could you tell us a bit about your CAREER project?

Zheng: This CAREER project aims to realize artificial muscle with mechanical and dynamic properties similar to natural muscle. In particular, this project considers the use of dielectric elastomers (DEs) that have compliance, resilience, and energy density per mass comparable to biological muscles. Like biological muscles, these materials can be self-sensing, allowing precise control of contraction or extension without auxiliary sensing schemes. The ultimate goal of the project is to achieve dexterous, lightweight, and energy-efficient prostheses using DE-based artificial muscles, in contrast to the heavy and inefficient electric motors of the current generation of robotic arms. The project incorporates aspects of bio-inspired design, device fabrication, and dynamic modeling, sensing, and control. The success of this project will help provide affordable, reliable, and comfortable prostheses to the estimated two million military veterans and civilians who have lost hands, arms, or legs to accidents, natural disasters, wars, diseases, or aging.

Q. How did you enter the field of dielectric elastomer artificial muscles?

Zheng: I entered this area when I started my assistant professorship at Wichita State University in 2013. A main motivation of the research was stemmed from several of my personal interactions with students and faculty with disabilities. I started to think about developing affordable and comfortable robotic assistive devices to help them. I explored different materials for sensing and actuation in prostheses and found that dielectric elastomer (DE), soft and natural for active artificial muscle, has great potential in such applications. My research group successfully developed a DE artificial muscle and tendon structure with integrated sensing and actuation capabilities in 2014, which was my starting point of this research.

Q. What do you see as some of the challenges and opportunities in dielectric elastomer artificial muscles?

Zheng: I have seen great opportunities in DE artificial muscles for prosthetic applications. DEs have built-in sensing and actuation capabilities which allow integrated sensing and feedback control without a bulky external sensor. The energy per mass density of DEs is comparable to human muscles, which makes the prostheses affordable in weight for people to carry on. DEs are compliant and resilient, which allows a comfortable prosthetic design. Although there are many advantages, I have also seen many great challenges in, e.g., bio-inspired artificial muscle structure design, safe operation of DE material, nonlinearities in sensing and actuation dynamics, integrated sensing and feedback control, and system integration.

Q. What are some of your experiences about integrating education in research?

Zheng: I developed a new graduate course on smart material sensors and actuators at Wichita State University. Although innovation is a fundamental basis for research, not all graduate students received proper training on innovation. I realized that smart material sensors and actuators are promising research areas in which students can learn how to innovate. To introduce this new class, I gave a seminar on electroactive polymers to graduate students, which led to a surprising 56 enrollments from the College of Engineering. I selectively gave lectures on special topics in shape memory alloys, ionic polymer-metal composites, dielectric elastomers, and piezoelectric materials, in which I covered basic techniques in smart materials, such as modeling, control, and fabrication. Then the students were encouraged to search for recent advanced technologies in smart materials, to summarize the advantages and disadvantages of existing technologies, and to develop their own ideas. The course sparked active interests and many great ideas on biomedical devices, bio-inspired robots, and energy harvesting and storage devices. For example, Ms. Alicia Keow developed a novel solar energy storage system using ionic polymer-metal composite in this class and presented her research at the 14th Annual Capitol Graduate Research Summit in the State Capitol of Kansas on March 10th 2017. She received the best project award in that summit. After this class, Ms. Keow decided to work with me to pursue her PhD study at the University of Houston.

Q&A with Dr. ShiNung Ching about his research titled "CAREER: System Theoretic Methods for Understanding the Dynamics of Cognition"

Q. Could you tell us a bit about your CAREER project?

ShiNung: Understanding how the human brain sustains cognition, i.e., our ability to sense and think, is a defining problem in neuroscience. This project supports the development of a research program to study the neural mechanisms of cognition through the lens of dynamical systems and control theory, and an educational program to highlight the connection between neuroscience and engineering. The program is motivated by: (i) the recognition that networks in the brain are, fundamentally, dynamical systems and, (ii) the theoretical supposition that such dynamics, and the control properties they confer, are consequential to cognition. As technologies for recording and manipulating brain circuits continue to develop, building an understanding of how the brain controls itself is a crucial precursor to eventual translational applications such as restoration of cognitive function through neurostimulation. Thus, this proposal seeks dynamics and control methods to reveal control strategies within the brain, so that eventually we can take advantage of this knowledge when devising stimulation-based interventions. Trained in both control theory and computational neuroscience, I will pursue this goal through the development of novel modeling and theoretical frameworks, and data-driven analysis approaches that will be used in concert with electrophysiological recordings from humans with quantifiable deficits in cognitive function.

Q. How did you enter the field of control theory and neuroscience?

ShiNung: Towards the end of my Ph.D., I became interested in the use of dynamical systems modeling to understand network-level phenomena in neural circuits. I subsequently discovered the work of Emery N. Brown and Nancy Kopell, who were using modeling to describe the effects of general anesthesia in the brain. I was fortunate to have the opportunity to become involved in that research as a postdoc, during which time I became exposed to many problems in neuroscience and brain medicine wherein control theoretic-principles can play a significant role.

Q. What do you see as some of the challenges and opportunities in control theory and neuroscience?

ShiNung: One of the major questions in neuroscience involves understanding how information is transformed and processed in neural circuits. At a systems level these circuits can be understood in terms of their dynamics and their subsequent input-output properties. As control engineers, we are very good at analyzing mathematical models of systems to elucidate such properties.

However, brain networks have a number of interesting dynamical features that render classical methods ineffective from an analytical perspective. Thus, I believe there is a tremendous opportunity in control theory to think about how to define neural circuit control properties and, perhaps more importantly, relate them to performance in the form of information processing. In turn, this will lead to other opportunities, including engineering new ways of modifying brain activity using stimulation for certain clinical applications.

Q. What are some of your experiences about integrating education in research?

ShiNung: As a faculty member at Washington University, I have been fortunate to interact with students who have a keen interest in research. As a consequence, my colleagues and I have been able to incorporate several brain-related activities into our senior-level control engineering course, as well as to develop a new graduate level course that spans topics in control theory and neuroscience. As well, over the past several years I have worked with educators in the St. Louis region to develop a teaching module that allows high school students to learn about neural engineering by visualizing their own brain activity using a low-cost electroencephalogram device. In addition to providing opportunities for students in our city, this has also been a great experience for my graduate students in terms of integrating them into the role of our University as a place for research, education and community engagement.

Q&A with Dr. Robert Gregg about his research titled "CAREER: Recovering and Enhancing Natural Locomotion in Changing Conditions with Powered Lower-Limb Prostheses and Orthoses"

Q. Could you tell us a bit about your CAREER project?

Bobby: Even with the help of modern prosthetic and orthotic (P&O) devices, lower-limb amputees and stroke survivors often struggle to navigate stairs, slopes, and uneven terrains. Emerging powered P&O devices could actively assist patients to enable greater mobility, but these devices are currently designed to produce one specific type of motion at a time. Hence, these devices cannot adapt to changes in the user's activity or the environment. A paradigm shift from task-specific, kinematic control approaches to task-invariant, energetic control approaches is needed for wearable robots to assist their human users across varying locomotor activities. This project will advance knowledge in the control of powered P&O devices by investigating a new task-invariant paradigm based on energy shaping, in which wearable actuators alter the parameters and/or formula for the human body's energy in closed loop to achieve more desirable dynamics and thus kinematics. Accordingly, the goals of this project are to 1) understand how to use wearable actuators to shape the energetics of the human body during locomotion, 2) determine specific changes to body energetics that lead to effective control strategies for powered prosthetic legs and powered leg orthoses (i.e., exoskeletons), and 3) understand how different gaits (i.e., kinematic patterns) emerge from body energetics in order to design task-invariant controllers for powered P&O devices. This work is significant by enabling individuals with a stroke or lower-limb amputation to freely navigate the different terrains in their homes and communities for an improved quality of life.

Q. How did you enter the field of robotic prostheses and orthoses?

Bobby: My graduate research at the University of Illinois was on energetic control of dynamic walking robots. As I was nearing the completion of my dissertation, I began looking for a new area to apply my expertise. Although I did not know much about prosthetics and orthotics at the time, I saw that as an area in need of robotic technologies to improve outcomes for lower-limb amputees and stroke patients. I decided to jump into that new area through a postdoctoral fellowship at the top rehabilitation hospital in the U.S., the Ability Lab (formerly Rehabilitation Institute of Chicago), where I spent three years learning about the clinical challenges in prosthetics and orthotics and how to translate my expertise into new clinical solutions. From there I founded my laboratory at the University of Texas at Dallas with the mission of developing high-performance wearable robots to enable mobility and improve quality of life for persons with disabilities.

Q. What do you see as some of the challenges and opportunities in robotic prostheses and orthoses?

Bobby: The research community has made great progress in the design and control of robotic prostheses and orthoses, but these technologies have faced many roadblocks to commercialization and clinical acceptance. Many of the research platforms we see in journal publications require expertise in control systems to configure for a patient, which is not feasible in a clinical setting. Even an expert team of researchers can spend many hours tuning the control gains and joint trajectories of a robotic knee-ankle prosthesis for each amputee user. These control systems are designed to track pre-defined reference gait patterns, which cannot adapt to varying environments, different users, or behavioral changes as the user relearns how to walk. Motivated by my dissertation research almost a decade ago, I see an opportunity to address these challenges with an energetic control paradigm as proposed in my CAREER project. Instead of tracking reference joint trajectories, controlling the energy of the human-robot system can produce different joint kinematics in response to forceful interactions with the environment and user. This could enable seamless adaptation to different users, activities, and environments, which will eliminate the need for tuning pre-defined kinematic patterns for all possible scenarios. The big question is how to control the energy of the human-robot system to yield correct kinematic behaviors, which I hope to address in my CAREER project.

Q. What are some of your experiences about integrating education in research?

Bobby: I am currently integrating my research into the curriculum of the Prosthetics-Orthotics program at the UT Southwestern Medical Center. This program provides clinical support for my research and also clinical training opportunities for my engineering students. In return, I am developing lectures on robotic prosthetics and orthotics technologies so that tomorrow's prosthetists are better able to adopt these technologies in their clinical practice. I also plan to offer a motion capture lab module in my gait lab so that prosthetics students become more familiar with gait analysis methods and quantifying gait abnormalities. These efforts will also facilitate greater interaction between clinical and engineering students and provide opportunities to collaborate in my CAREER research.

Q&A with Dr. Ross L. Hatton about his research titled "CAREER: Geometric Understanding of Locomotion"

Q. Could you tell us a bit about your CAREER project?

When systems have joint limits (i.e., they have limbs instead of wheels or propellers), their ability to locomote depends on how effectively they can change their interaction with the environments at different points in a gait cycle. When these interactions are first-order constraints and they change smoothly with the system's shape, locomotive effectiveness can be characterized via a Lie bracket (a structure closely related to the curl of a vector field). This project seeks to extend this concept to include direction-dependent effects (e.g., friction from backwards-pointing spines or bristles), second order dynamics (e.g., elastic tails or wings in air), infinite-dimensional systems, and hybrid systems (e.g. walkers that can lift their feet from the ground. Specific systems that will be made accessible to geometric analysis by this project include, 1) systems with many shape variables, whose curvature is a high-dimensional structure; 2) hybrid systems, which have "corners" in their dynamic curvature; 3) ratcheting systems, whose reaction forces depend on the sign of the relative motion; 4) elastic systems, whose gait cycles partially emerge from their passive dynamics; and 5) gliding systems, whose gait effectiveness is better characterized by momentum transfer than by displacement induced.

Q. How did you enter the field of geometric mechanics?

Ross: In graduate school I worked on snake robots. Working with the physical geometry of the snakes led me to work on the abstract geometry of their physics of locomotion.

Q. What do you see as some of the challenges and opportunities in geometric mechanics?

Ross: Much of the foundational work in this field is in the language of mathematics, which can make it difficult for an engineer to adopt the tools it provides. A large part of my work aims to bridge this gap, and translate the concepts into more accessible language.

Q. What are some of your experiences about integrating education in research?

Ross: Bringing concepts from differential geometry into engineering and the educational process pushes me to distill them down to their essential components, which I believe results in a stronger, more robust understanding of the principles.

Q&A with Dr. Hae Young Noh about her research titled "CAREER: Structures as Sensors: Elder Activity Level Monitoring through Structural Vibrations"

Q. Could you tell us a bit about your CAREER project?

Haeyoung: Smart buildings are designed to sense, understand, and respond to occupants' needs to enhance their quality of life in a sustainable way. For example, elder care facilities aim to maintain or improve the quality of life and independence of elders while reducing costs and capacity needs for care-professionals. One key to achieving this goal is to understand the activities of each occupant. Existing solutions to monitor occupants, such as vision, acoustic, motion, and force sensors and mobile devices, have strict installation requirements. These requirements lead to intrusive and dense deployment, or require active user involvements. Instead, this project builds on the fact that occupants create building vibrations when they walk around. The project goal is to enable real-time robust inference of individual occupants' walking activity levels, from building floor vibrations. Using building vibration to monitor occupants allows non-intrusive and scalable monitoring with inexpensive vibration sensors. More generally, this research will enable smart buildings to sense, track, and predict the status of occupants in a maintainable way using "structures as sensors" and thus enable future occupant-aware applications. The resulting analysis tools for noisy vibration data will advance the science in signal processing and uncertainty modeling, which is widely applicable to other fields, including structural health monitoring, vehicle dynamics, manufacturing, and earthquake engineering.

Q. How did you enter the field of human activity monitoring through building vibrations?

Haeyoung: Initially, I was investigating building vibration data for structural damage diagnosis purposes. The building vibration responses often contain lots of noises incurred by occupants, machineries, and water systems indoor, so we used to filter them or conduct experiments during quiet hours with less activities. Then, one day we realized various human activity information (such as location, identity, activity type, activity level, etc.) can also be inferred from the building vibration responses, just like structural damage information. Further, sensing humans through structures provides nice benefits due to its indirect nature, like non-intrusiveness, less perceived privacy concerns, and simple and robust installations. A followup conversation with my partners in eldercare revealed a great potential for using this technology for elderly activity monitoring and fall prevention, which inspired my research pursuit in this field.

Q. What do you see as some of the challenges and opportunities in human activity monitoring through building vibrations?

Haeyoung: The main challenge in this research is to extract target information like "grandma is likely to fall after 10 steps," and "today grandpa got out of his routine morning activity sequence and sat down longer" from very noisy signals. Building vibration responses are induced by multiple sources such as people walking around, water facet, fans, etc., which makes the separation of individual source information difficult. On the other hand, such mixture enables the signals to have rich information and many different information can be extracted from only sensing building vibration. This significantly reduces installation and maintenance costs.

Q. What are some of your experiences about integrating education in research?

Haeyoung: I integrated research components into project courses for undergraduate and graduate students at Carnegie Mellon. These courses incorporate smart building applications, which involve sensing, signal processing, probabilistic modeling, and decision making. I focus on hands on experiences to show students how knowledge from different areas can be synthesized to achieve a novel goal and benefit people. In addition, initial exploratory ideas and applications for the research are tested through course projects. Further, I work with local middle school girls through the Summer Engineering Experience program at Carnegie Mellon to increase gender diversity in science and engineering at the critical time when girls develop their future career interests.

Q&A with Dr. Simona Onori about her research titled "CAREER: Integrated Modeling and Control of Aftertreatment Systems for Clean, Efficient and High-Performing Gasoline Direct Injection Engines"

Q. Could you tell us a bit about your CAREER project?

Simona: Gasoline direct injection engines have better fuel economy than more conventional port fuel injection engines. But the new technology results in higher fine-particle emissions that can be hazardous to people's health. As the number of vehicles using GDI engines increases, the need to safeguard public health by mitigating particulate emissions becomes an urgent social concern. Particulate emissions are one of the most unwanted but least understood hazards from GDI engines. This Faculty Early Career Development (CAREER) project will enable future vehicles to benefit from the improved efficiency and performance of gasoline direct injection (GDI) engines, without suffering from increased soot emissions. An integrated approach is necessary because engine operating conditions determine oxygen and fuel content and temperature of the exhaust gas, which influence the output of the catalytic converter, which in turn governs soot accumulation and oxidation in particulate filters. While the dynamics of diesel engine particulate filters are well understood, particulates produced in GDI engines have substantially different characteristics. In this CAREER project, we will use advanced modeling techniques to predict when soot will accumulate and when to burn it off to prevent plugs and keep the engine running smoothly and efficiently. The proposed modeling framework is at the intersection of macroscale modeling, numerical simulations and optimization theory. System-level models of the engine, catalytic converter, and gasoline particulate filter will be integrated across length scales. The framework will enable formulation of low-order models of aftertreament systems suitable for real-time optimization-based control, based on systematic and rigorous reduction of continuum models while maintaining accuracy and fidelity.

Q. How did you enter the field of aftertreatment and emission control research?

Simona: When I started my tenure-track position at Clemson, I had the great opportunity to be the PI of an industry sponsored project on control of advanced aftertreatment systems back in 2014. That's when I started being passionate about the aftertretament system topic.

This NSF CAREER focuses on the challenges posed by the modeling and control of new generation emission control devices, such as Gasoline Particulate Filters (GPF). These filters are used to reduce Particulate Matters (PM) – fine particles that are dispersed in the air – released by the Gasoline Direct Injection (GDI) engines.

This project will enable new exhaust gas aftertreatment technologies for GDI engines, based on a novel macroscale modeling framework, and the generation of numerical tools for optimization strategies.

Q. What do you see as some of the challenges and opportunities in the aftertreatment and emission control research?

Simona: As more and more automakers make the claim that they will end the production of only-engine vehicles, one of the challenge/opportunity for control engineers is the integration and control of technologies like, for instance, GDI, GPF, and battery and supercapacitors, in a coordinated fashion that will preserve longevity of some of those components while obtaining the most of the vehicle performance. Multi-objective optimization constrained problems, for both offline and online implementation, will be a dominant research area in my mind. Another challenge is the problem of online estimation of internal, associated-with-aging, parameters of components like battery and GPF. These systems are described by nonlinear PDE.

Q. What are some of your experiences about integrating education in research?

Simona: I always strive to bring recent research developments in my classes. My field of research is continuously evolving and it is mandatory to update the class material with the latest findings and technologies used in the field. As part of this NSF CAREER my goal is to create a graduate course that collects results from the project, titled "Modeling and control of exhaust gas aftertreatment systems", to be offered also as distance education course to industrial partners.

News Briefing

Professor Marcia O'Malley received the George R. Brown Award for Superior Teaching at Rice University for 2016-17.

The 2016 IEEE/ASME Transactions on Mechatronics Best Paper Award was awarded to "Adaptive Torque and Passivity-Based Impedance Control for Series Elastic Actuators: A Time Domain Approach," by Dylan P. Losey, Andrew Erwin, Craig G. McDonald, Fabrizio Sergi, and Marcia K. O'Malley. DOI: 10.1109/TMECH.2016.2557727.

Special Journal Issue in Memory of Karl Hedrick and John Moskwa: A special issue titled "Vehicle Powertrain Research" will be published in the International Journal of Powertrains in September 2017 in memory of Professor Karl Hedrick and Professor John Moskwa. Guest editors: Dr. Per Tunestål (Lund University) and Dr. Mahdi Shahbakhti (Michigan Tech University).

TENTH ASME DYNAMIC SYSTEMS AND CONTROL CONFERENCE 2017

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DETAILS CAN BE FOUND ON THE CONFERENCE WEB SITE AT HTTP://ACC2018.A2C2.ORG

The 2018 AMERICAN CONTROL CONFERENCE will be held Wednesday through Friday, June 27-29, at the Hilton Milwaukee City Center Hotel in the heart of Milwaukee, Wisconsin – mere steps from the Lake Michigan shoreline. The conference venue is near nightlife, restaurants, shopping, and entertainment, including the Henry Meir Festival Grounds - host to the world's largest music festival, SummerFest, which will celebrate its opening day alongside the ACC.

The ACC is the annual conference of the American Automatic Control Council (AACC), the U.S. national member organization of the International Federation for Automatic Control (IFAC)). National and international society co-sponsors of ACC include American Institute of Aeronautics and Astronautics (AIAA), American Institute of Chemical Engineers (AIChE), Applied Probability Society (APS), American Society of Civil Engineering (ASCE), American Society of Mechanical Engineers (ASME), IEEE Control Systems Society (IEEE-CSS), International Society of Automation (ISA), Society for Modeling & Simulation International (SCS), and Society for Industrial & Applied Mathematics (SIAM).

The 2018 ACC technical program will comprise several types of presentations in regular and invited sessions, tutorial sessions, and special sessions along with workshops and exhibits. Submissions are encouraged in all areas of the theory and practice of automatic control.

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