

In this issue of *IEEE Control Systems Magazine (CSM)* we speak with Christos Cassandras, 2012 IEEE Control Systems Society (CSS) president. Christos is head of the Division of Systems Engineering and professor of electrical and computer engineering at Boston University. He served as editor-in-chief of *IEEE Transactions on Automatic Control* from 1998 through 2010, and he has held numerous positions in CSS. He is the author of over 300 refereed papers and five books, and he is the recipient of several awards including, most recently, the 2011 IEEE Control Systems Technology Award.

We also speak with Richard Braatz who will serve as editor-in-chief of *CSM* beginning in 2012. Richard is the Gilliland Professor at the Massachusetts Institute of Technology. He has served on the editorial board for several control journals, including *IEEE Transactions on Automatic Control*, has been deputy editor of *CSM* since 2010, and has held various other positions in CSS. He is the author of more than 200 research papers and three books and is a recipient of the Donald P. Eckman Award and the Antonio Ruberti Young Researcher Prize.

CHRISTOS CASSANDRAS

Q. Congratulations on your new role in the IEEE Control Systems Society (CSS). You've been extremely active in CSS over the years. Which of the numerous roles have you found the most rewarding—thus far?

Christos: Thank you, and let me state the obvious by saying that it is an honor to serve our Society as its 2012 president. To answer your question, the most rewarding CSS-related activity I have been involved with to date was undoubtedly that of editor-in-chief of *IEEE Transactions on Automatic Control* for 12 years. I had the opportunity to design one of the first Web-based journal submission processing and reviewing systems for the transactions in 1999. I then witnessed one of the most dramatic growths in submissions—the number of full papers submitted to

the journal more than doubled between 2003 and 2009. This posed enormous challenges to maintain the high quality of the reviewing process without creating undue delays in overall paper handling. Above all, however, this position gave me the opportunity to monitor the pulse of our scientific community and observe new trends and research directions from a unique vantage point. There is no question that my own research activities were influenced by this experience.

Q. How did your educational background bring you to the systems and control field?

Christos: Since my high school days, I have been fascinated by the use

of mathematics to model physical processes and then make predictions about them. This was reinforced when I was first exposed to the theory of systems and control in college and realized that we can actually use mathematics to make a system behave in a way we want—and then actually see that *really* work. Here, I must give credit to my very first teacher in systems and control, Bob Barmish, who taught a course I took at Yale University, from which I graduated in 1977. I then went to Stanford University, where I found out that not only can we “make a system behave” using mathematical techniques, but we could also make it achieve the best possible desired behavior—

this was my exposure to optimization and optimal control in a course I took with Arthur Bryson. In the same course, we touched upon game theory. In a private conversation with Arthur Bryson, I told him I would like to make some aspect of game theory my Ph.D. research topic, and he suggested that I should then do so with his colleague, Yu Chi (Larry) Ho, at Harvard.

To make a long story short, I ended up at Har-

vard at a time when Larry Ho was moving away from games and into a new, little known, or researched area that involved weirdly behaving dynamic systems one encounters mostly in the “man-made” rather than the “physical” world. A few years later, I completed



Christos Cassandras, 2012 president of the IEEE Control Systems Society (CSS), and head of the Division of Systems Engineering and Professor of Electrical and Computer Engineering at Boston University.

a PhD thesis on discrete-event dynamic systems, a term that eventually became a staple not only in our field but also in disciplines such as operations research, industrial engineering, and computer science. I must point out that Larry Ho has had a profound influence on my approach to a career of teaching, research, and making an impact in society. However, to best appreciate this kind of career, one must also experience the “real world.” And so I did upon graduating from Harvard by working in a small startup company in Cambridge specializing in manufacturing automation. But the lure of academia was always there, and in 1984 I joined the Department of Electrical and Computer Engineering at the University of Massachusetts in Amherst. I worked on discrete-event systems and maintained strong contacts with the real world through consulting engagements that continually allowed me to find motivating problems for my more theoretical academic research through the years.

In 1997, I came to Boston University, joining both the Manufacturing Engineering Department and the Electrical and Computer Engineering Department. A few years later, together with several colleagues, we cofounded the Center for Information and Systems Engineering, an exciting environment for interdisciplinary research centered around the study of systems which I continue to enjoy. In 2008, the Division of Systems Engineering was established at Boston University, and I have been its inaugural Head ever since.

Q. What are your current research interests?

Christos: I had the good fortune to be involved in the 1980s with the creation of a new area within our field, what is now widely known as discrete-event systems. To this day, I remain deeply involved with research related to this class of dynamic systems, especially studying them in stochastic settings and seeking to achieve optimal performance. This is particularly challenging when there are no analytical

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expressions to capture the dependence of various performance metrics on critical design and control parameters. It turns out, however, that one can efficiently obtain performance sensitivity estimates from directly observable data despite the fact that the dynamics in these systems are very complex and the stochastic processes involved often do not fit standard models. This has given rise to a rich perturbation analysis theory for discrete-event systems and associated optimization methods, many of which have seen real-time applications in a variety of settings, from manufacturing to computer networks and transportation systems. One of my favorite application projects, for example, is the use of these techniques to develop better dispatching control algorithms for elevators viewed as discrete-event systems.

Once it became clear that there is a realm of systems whose dynamics are not time driven but rather event driven, it is not surprising that combining the two has resulted in “hybrid” systems. I became interested in the modeling, control, and optimization of these systems in the mid 1990s and, like many others, have come to recognize that just about every modern technological system is now hybrid since it combines physical components whose dynamics are time driven with computer-based components for its operational control that obviously have event-driven dynamics; hence, also the now popular term “cyberphysical system.” Over the past decade, perturbation analysis theory for discrete-event systems has in many ways been reinvented and adapted to the broader class of hybrid



Christos Cassandras with wife Carol Kamm and daughter Monica during a safari in Tanzania and Kenya in 2006.

Profile of Christos Cassandras

Current position: Head, Division of Systems Engineering, and professor of electrical and computer engineering, Boston University.

Visiting and research positions: Harvard University; Universite Catholique de Louvain, Louvain-la-Neuve, Belgium; Tsinghua University, Beijing, China.

Contact information: Division of Systems Engineering, 15 St. Mary's St., Boston University, Brookline, MA 02446; +1 617 353 7154; e-mail: cgc@bu.edu; http://vita.bu.edu/cgc.

IEEE CSS experience highlights: Editor-in-chief, *IEEE Transactions on Automatic Control* (1998–2009), editor, Technical Notes and Correspondence (1994–1998), associate editor (1991–1993); vice president, Publication Activities, (2010); Board of Governors since 1996; chair, Technical Committee on Control Theory (1994); chair, Working Group on Discrete Event Systems (1989–1993); general chair, 43rd IEEE Conference on Decision and Control, 2004; program chair, 38th IEEE Conference on Decision and Control, 1999.

Notable Awards: Harold Chestnut Prize, International Federation of Automatic Control, 1999; IEEE Fellow, 1995; Fellow, International Federation of Automatic Control, 2008; Lilly Fellow, 1991–1992; IEEE Distinguished Lecturer, 2001–2004; CSS Distinguished Member Award, 2006; IEEE Control Systems Technology Award, 2011.

systems with numerous ramifications to optimization and optimal control.

About ten years ago, wireless sensor networks made a big splash with the promise of turning the globe into one huge network where everything is continually monitored and actuators control our environment, from our living quarters to every aspect of our cities and our energy generating and production resources. While the monitoring part is within reach, the actuating part is not, and that's where a thorough understanding and application of control principles and techniques is called for. With several colleagues at Boston University, I have become involved in research problems related to sensor networks and their broader implications. For instance, highly distributed networked systems require on-board energy sources with capabilities that current battery technology is unable to provide. Thus, I have become interested in understanding the dynamic behavior of batteries and how we can manage their use to save power and prolong the life of a wireless sensor network. At the same time, I realized that much of our theoretical

work could be readily tested in laboratories with fairly inexpensive small mobile robots acting as the nodes in a sensor network. So, without claiming any expertise in robotics, I have also developed with my graduate students a laboratory where we experiment with teams of autonomous agents and unmanned vehicles. My interest is in the cooperative aspects of such teams and related issues that arise in distributed control and optimization. For example, how can we achieve desirable system behavior with minimal communication since such communication consumes too much valuable energy?

Returning to my involvement with discrete-event systems in their formative years in the 1980s, I always felt that the real world is at least as much event driven as it is time driven. The revolution of digital electronics has made us comfortable with the idea that digital clocks can drive just about all of our technological systems. But as our world is becoming largely wireless and battery technology is progressing seemingly at a snail's pace relative to everything else, one must question the inherent inefficiency of time-driven

sampling or the mindless time-driven exchange of useless or redundant information instead of more smartly deciding when to offer information and what this information ought to be. I believe that fields such as control, communication, and information theory should examine event-driven approaches, and I have been happy to see a recent movement toward event-driven control, where I view my own research interests have existed for quite some time.

Finally, I should mention that I have also had the good fortune to channel some of my research interests through nonacademic organizations. For example, I mentioned earlier some application projects on elevator systems that were inspired and supported by Otis Elevator. I've had similar experiences with large manufacturing organizations during the era of building "factories of the future" some 20 years ago. More recently, I collaborated with The MathWorks seeking to bring discrete-event simulation into the family of Matlab and Simulink-based scientific computation tools. This has given me the chance to appreciate the challenges of bringing together time- and event-driven elements in a common computational engine for modeling, design, control, and optimization of hybrid systems, something I had previously taken pretty much for granted.

Q. What do you see as some of the priorities for ensuring the future success and impact of control-related technology?

Christos: It is fair to say that since its golden era of the 1960s and 1970s, control theory has evolved to a point where it is perceived by funding agencies, industrial organizations, and the science and engineering communities at large as a well-respected engineering discipline playing mostly a supporting role for other disciplines. Indeed, control theory has been described as ubiquitous or as the indispensable "invisible" technology that powers many others. I emphasize that this is a perception, implying that the limited recognition of successes in our field may well

be as much a result of inadequate advocacy as of any other factor. Along these lines, I would like to point out the credit that Tariq Samad and Anu Annaswamy deserve for their recent great effort in editing "The Impact of Control Technology," published in January 2011, which contains numerous success stories of control engineering in all aspects of modern technology.

In my opinion, the work and scholarly output of our research community today goes way beyond the traditional definition of "control theory." Our expertise allows us to analyze systems, design new and better ones, and manage their operation in innovative ways that only the understanding of fundamental concepts such as dynamics and feedback can enable. A typical attendee of our conferences is in fact a system scientist or system engineer as much as just a control expert. In short, our field is much broader than many consider it to be, and I believe that we need to adopt such a point of view, realizing that systems and control is a branch of engineering (and, to some extent, science as well) that encompasses a large number of areas. We once focused on controlling aircraft and industrial machining processes, yet we now "control" computers, commercial devices, and wireless networks, pretty much anything with an on-off switch. Perhaps the mathematical challenges of designing and controlling some of these systems are not as exciting to some, but the fact is that even deciding when to switch something on or off to meet certain goals is still control.

So, to answer the question about ensuring future success, I believe the key is to broaden our perspective, occasionally redefine what we already do, and look at *all* aspects of modern technology as opportunities to design and control increasingly complex dynamic systems that come in all sorts of flavors and colors. My sense is that many in our midst are in fact doing that and, as an example, I would like to mention how the CSS community has embraced event-driven systems to go along with the beloved $\dot{x} = Ax + Bu$.

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Q. How do you see your role as president of the Society, and what are your priorities for the next year? Are you planning any new initiatives?

Christos: Looking at the Society through the prism of financial, conference, and publication activities, it is easy to see that it is in excellent shape and has been that way for several years now, despite worldwide economic problems that have affected our members as well as the parent IEEE organization. A lot of credit must go to the CSS leadership, starting with my recent predecessors, such as Rick Middleton, Roberto Tempo, and beyond. Our finances have been managed cautiously, yet without resorting to pointless frugality when there are worthwhile causes to support. Our conferences are very well attended, and I continue to be amazed at the extent to which CSS members work hard as volunteers in capacities that range from putting together extensive technical programs to working out details at the local arrangement level. This commitment has enabled us to maintain low registration fees and overall costs since we do not rely on expensive outside entities to manage our registrations, proceedings, or even marketing. Our publications have seen continuing submission growth and enjoy the respect of the broader scientific community as measured through the usual impact factor metrics. There is every reason to believe that the basic model of governance of the CSS is one that should be sustained at every cost. Yet, my involvement with the Society has also taught me that we are not

afraid to make adjustments and adapt to new needs and requirements as they appear. In other words, we are always prepared to make any change that is called for in response to all the new external stimuli that we sense.

A case in point is the observation that there is an increasing number of instances that involve ethical violations in publishing, ranging from those who abuse our reviewing and editorial systems by submitting multiple heavily overlapping versions of the same paper to cases of blatant plagiarism. We have, therefore, adopted new tools for detecting such potential cases and established a new committee that will be carefully reviewing them to ensure fair treatment and to ultimately send a clear message that well-documented cases of ethical violations will not be tolerated within our community. Having personally witnessed several such cases while acting as editor-in-chief of *IEEE Transactions on Automatic Control*, I am quite sensitive to this issue and intend to ensure that our plan for controlling this problem goes forward and is successfully implemented.

Along similar lines, a concern that remains among our members is the lack of clarity regarding the difference between journal publications and conference proceedings. Let me not get into the details of this issue here. I only want to say that I plan to continue working with our editors and the CSS vice president for publications to achieve a synergy between our conference and journal publications with the ultimate goal of

The 2012 CSS Executive Committee

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optimizing how our research results are disseminated.

In a different vein, I would like to see the CSS be an active and leading participant in the general globalization trend within IEEE. There is no question that we are an international scientific community, and we have long had programs in place—such as support for members from disadvantaged countries—to recognize and nourish this fact. I would like to work toward increased participation in our activities from colleagues and emerging research groups in new parts of the world, and I'd like to see more of our conferences held in such places as South America.

I started out my response to this question by looking at the Society “through the prism of financial, conference, and publication activities.” This covers the management side of the Society, leaving everything else that would broadly come under the umbrella of intellectual activities. Here, a president has much less influence, and I would only like to return to some of the ideas I shared

with you in responding to the previous question on ensuring the future success and impact of our field. I hope that with the help of my friends and colleagues in the CSS leadership we can all raise the awareness of the points I made earlier regarding how much broader our range of activities has become under the heading of systems and control and not just control. Even if my assessment is not fully accurate, I hope that through a continuing dialog and educated soul-searching we can move forward to properly define who we really are and what our educational and scientific missions are.

Q. The young members in our field—especially students—are the future of CSS. How can we expand their participation and role in CSS?

Christos: I completely agree with the observation that students are the future, and I believe there are two aspects to answering the question. First, at the level of each mature CSS member (be it in academia or not), we need to provide role models for stu-

dents who are at least intrigued by our field. It is our responsibility to share with them our excitement, to show them what lies ahead as much as what has been accomplished to date, and to set examples for professionalism and proper scientific conduct. I think this aspect is rather self-evident. Second, as a Society, we can facilitate the participation of students in our organized activities, mostly conferences. Along these lines, we have launched and are sustaining programs for reduced registration fees and for free membership to the CSS. I am also very much in favor of student-led workshops, which I have seen emerge and grow in recent years and where students take ownership of the organization and the technical program of such workshops. Finally, the CSS has in recent years instituted a process for funding and promoting outreach activities, some of which include such workshops or efforts to promote systems and control at the high-school level worldwide. The CSS Executive Committee in the last few years has also tried to combine its two annual meetings with such outreach workshops that bring together students and young researchers from the areas where these meetings are held.

Q. What are some of your interests and activities outside of your professional career?

Christos: I like traveling, especially to places outside the beaten path. I have also always been interested in languages, so traveling gives me a chance not only to practice the languages I speak, but also learn about new ones. I enjoy reading and writing (not only technical papers), though finding time to do either in recent years has been quite a challenge.

Q. Thank you for your comments. We wish you success as 2012 CSS president, and we look forward to reading about your ideas in the upcoming “President’s Message” column in CSM.