MIROSLAV KRSTIC

Q. How did your education and early career lead to your initial and continuing interest in the control field?

Miroslav: I had a remarkable educational and research experience with Petar Kokotovic, as his first Ph.D. graduate at the University of Calfornia, Santa Barbara (UCSB). Petar mentioned an open problem when I arrived in Santa Barbara, which a number of top researchers in adaptive and nonlinear control had tried and given up on. Unaware of this context, I solved the problem before the classes started. This had an irreversible confidence-building effect on me as a researcher.

I defended my Ph.D. a little more than three years later, with 12 journal papers and the student best paper awards at both the IEEE Conference on Decision and Control and the American Control Conference. My dissertation won the campus-wide best dissertation award and, with additional contributions from Petar and Ioannis Kanellakopoulos, was published in 1995 as a book that has since become a classic.

However, with highly theoretical results and my still-limited English, my record wasn't translating into faculty job offers in electrical engineering departments to which I was applying. But several mechanical engineering departments saw promise in my work in nonlinear and adaptive control, with applications involving fluids, and I made a permanent and fortunate academic transition into mechanical engineering.

Alas, I soon came to the realization that, while nonlinearity is ubiquitous in mechanical engineering, only a small fraction of research in the discipline involves ordinary differential equations (ODEs). A far larger share of problems worthy of academic study appeared to be governed by partial differential equations (PDEs). As an electronics engineer, I had zero training in PDEs. However, I had an intuition that fluid, thermal, elasticity, and other problems called for an infinite-dimensional version of the backstepping methodology that I developed for ODEs.

I worked my way from designs for basic PDEs to those of increasing generality. I aimed to get to the "crowning goal" of Navier–Stokes (and magnetohydrodynamics) PDEs by the conclusion of my career. However, I attained that goal in just a half-dozen years with the help of gifted students, particularly Andrey Smyshlyaev and Rafael Vazquez. Gratifying examples of industrial adoption of PDE backstepping estimation and control are lithium-ion batteries and oil drilling.

Q. What are some of your research interests?

Miroslav: Besides PDE control, which I previously mentioned, and control of delay systems (a small island in a vast PDE ocean), I have put considerable energy into the development of extremum-seeking (ES) algorithms. This effort has been of remarkable consequence, with thousands of papers in the wake of my proof of stability of such algorithms in the late 1990s, and a nearly limitless expansion into robotics, autonomous systems, and other applications. I am humbled by the impact that ES has had, through students that I've educated at UCSD. ES runs on the Mars Rover and has enabled a 200-fold increase of the area density in microchips, like those that run on your iPhone, yielding an impact in billions of dollars for the semiconductor photolithography industry alone.

Miroslav Krstic at the University of Sheffield, United Kingdom.

Q. What courses do you teach relating to control? Do you have a favorite course? How would you describe your teaching style?

Miroslav: I have taught undergraduate courses in controls and signals and systems and graduate courses in nonlinear systems, nonlinear control, adaptive control, system identification, and even robust control (based largely on how I learned this subject from Mohammed Dahleh at UCSB).

In the last five years, my administrative duties have limited me to teaching only one course per year. I chose that course to be Nonlinear Systems and teach it, naturally, based on Khalil's superb textbook. My experience is that, without examples, even the students' theoretical grasp of the material is limited. So I often tilt the time-imposed tradeoff between proofs and examples in favor of examples.

Q. What are some of the most promising opportunities you see in the control field?

Miroslav: I can only give a credible opinion on the promising opportunities for what I do, and even this opinion will probably change three times before this interview appears in print.

While it is common to quote networks and data science in offering a vision for our field's future, I feel that our field's present calls for scientifically more satisfying solutions than those currently available. For instance, systems modeled by coupled/networked PDEs (and ODEs) are of unparalleled relevance in biomedical, industrial, and even societal systems.

I anticipate that increasing numbers of researchers in our field will be

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Angela and Miroslav Krstic enjoying an afternoon at the University of Chicago during a college tour with their youngest daughter.

Profile of Miroslav Krstic

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drawn by the fundamental character of such PDE models, to design controllers and estimators for physical systems in their "native" setting, and to have a lower barrier of collaboration with experts in basic sciences. What seemed a decade ago as methodological utopia—explicit controllers for PDEs—will eventually become as common as ISS, model predictive control, or linear quadratic Gaussian became within a couple of decades after their launch.

Q. You are the author of 12 books in the control field. What topics do these books cover?

Miroslav: My first book/dissertation was on the adaptive control of nonlinear systems, and my second book extended this effort from deterministic to stochastic systems. I have three books on ES: one on deterministic tools, one on stochastic ES, and one using ES not for optimization but for stabilization. I have written four books on control of PDEs: one is a basic textbook (which won the IFAC Chestnut prize and led to my selection as the Ragazzini awardee), and another one is on adaptive control of parabolic PDEs. The other two are on control of turbulent fluids (one for limited Reynolds numbers and the other with no Reynolds number restrictions and for magnetic fields, like in nuclear fusion). Finally, three of my books are on delay systems: one on predictor feedback for nonlinear systems, one for systems with delays that depend on time or even on state, and one on stability of input-delayed systems under predictor approximation and sampled-data implementations.

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

Miroslav: I go through phases. Currently my soft spot is for Greek and Roman classics and their derivatives, like Edward Gibbon. Many friends know of my electric guitar passion, and some have seen me perform at the Information Theory and Applications Workshop banquets at UCSD. My favorite guitar player is 1970s-era Michael Schenker. I have several 1970s Gibson Flying Vs, custom shop Strats, and classic Marshalls. Unfortunately, my instrument collection has been collecting dust since I began my administrative service at UCSD.

On the classical music side, examples of what I currently enjoy are Dvořák's cello concerto in B minor and Mahler's symphonies. Petar Kokotovic is partly responsible for my getting hooked on ballet and art museums.

Q. Thank you for your comments.

Miroslav: You're welcome.