In this issue of *IEEE Control Systems Magazine*, we speak with Marco C. Campi, who is a professor of control and system identification in the Department of Information Engineering at the University of Brescia, Italy. He is a Fellow of IEEE and serves as the chair of the IFAC Technical Committee on Modeling, Identification, and Signal Processing (MISP). From 2001 to 2006, he was a Distinguished Lecturer of the IEEE Control Systems Society and, in 2008, he received the George S. Axelby Outstanding Paper Award.

Next we talk with Xiaohua Xia who is a professor in the Department of Electrical, Electronic, and Computer Engineering at the University of Pretoria, South Africa. He was academically affiliated with the University of Stuttgart, Germany, the Ecole Centrale de Nantes, France, and the National University of Singapore before joining the University of Pretoria in 1998. He has authored/coedited two books and written over 200 journal and conference papers and is a Fellow of IEEE.

Following, we speak with Zhihua Qu who is a professor and chair of the Department of Electrical Engineering and Computer Science at the University of Central Florida. He has authored three books and written over 100 journal articles and 200 conference papers and is a Fellow of IEEE.

We conclude with Guoxiang Gu who is a professor in the Department of Electrical and Computer Engineering at Louisiana State University (LSU). He has coauthored two books and about 150 journal and conference papers and is a Fellow of IEEE.

MARCO C. CAMPI

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

Marco: My education was important, but it all started by accident. In the 1980s I was an undergraduate student at the Politecnico di Milano pursuing a degree in electrical engineering. It was a long degree consisting of five years of coursework, followed by a substantial final project. During my studies, it soon became clear to me that not all courses were equally intellectually stimulating; while some methodological courses were exciting and presenting great stuff to explore, other courses were more descriptive and mundane. It was around that time that I began to develop a fascination for mathematics. I remember those years with nostalgia, when, together with my old and dear friend Marco Fuhrman, we were passionately discussing mathematical subjects. Marco was great at discovering the neatest books on diverse topics in mathematics, and he shared those books with me. After two years, the students at the Politecnico of Milano were asked to choose a specialization. I chose control just because it had a reputation for being the most methodologically oriented stream. So, I bumped into control by accident. But then I liked it. To a large extent this was to the credit of some outstanding instructors I met. Sergio Rinaldi, who lectured on systems theory in the third year, was a histrionic guy with a magnetic personality. Guido Guardabassi, who taught automatic control in the fourth year, was an extraordinarily deep analytical thinker, and I loved his sophisticated lecturing style.

Marco C. Campi (photo courtesy of S. Garatti).

The year after that I met Arturo Locatelli, who reinforced my love for mathematics by teaching me the beauty of the geometric approach to control, and Claudio Maffezzoni, who showed me how exciting a course in applied control can be. But it was Sergio Bittanti, professor of system identification, who first introduced me to inverse problems, from the data to the model, which became my main interest through the following years. Sergio made a great impression on me for the passion he had for the discipline he taught, and he passed on to me his love for science as only great mentors can do. Sergio also introduced me to scientific research as I undertook my final project on the theoretical analysis of time-varying identification methods under his supervision. The rest came by itself. I joined the Department of Electrical Engineering of the Politecnico of Milano, informally at first, and then as a research fellow with the Center for Systems Theory. In those years of my early career, my biggest

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fortune was that of being in a vibrant environment, with many people who were supportive, without ever enforcing their way of thinking or imposing their topic of research on me. So I always chose directions out of interest and passion.

Q. How has your research evolved through the years?

Marco: My research has mostly evolved along a continuous path, with a lot of winding, but without big jumps. I think this is the result of my attitude that I get interested in things that have some relation to the problems and ideas I am carrying in my mind at a point in time. It is perhaps a limit since it may lead to a "local exploration." Still, looking in retrospect, I think I have been traveling quite a bit of road in research topics during my 20-year academic career. I started by exploring system identification and then moved to adaptive, data-based, and stochastic control. I did a lot of work on these topics in the 1990s. At those times, I also commenced research in learning theory, while studying Bayesian learning and learning with priors. Learning is intimately tied to optimization, and data-based optimization became the central focus of my attention starting around the year 2000. At present I am applying data-based optimization to robust control, Weber problems, and machine learning, with a specific interest in heart defibrillation schemes, but no doubt my main interests remain in the foundational aspects of data-based optimization.

Along this 20-year journey in research, a major role has been played by the persons I met and those I did research with. In 1992, I spent a fantastic semester in Canberra, working with Matthew James on risk-sensitive stochastic control. Some people say that Canberra is a boring place, but I loved it, especially the natural environment; the birds in Canberra are absolutely amazing. My visit in the summer of 1995 to the University of Illinois at Urbana-Champaign was a milestone in my working life. That summer was one of the hottest of the last century in Urbana-Champaign, and hot in the American midwest means really hot, but to me it was the best possible place to be. I did research with P.R. Kumar, who is a real scholar and a wonderful person in all respects. I learned plenty from him about adaptation and stochastic control, and I truly loved his free and easy approach to things, with an uncommon ability to distinguish things that matter from "details." I first visited the University of Melbourne in 1998, and I am still a frequent visitor there. I owe this to Erik Weyer. He is a gifted and deep researcher, and I am truly grateful to Erik for many years of friendship and enjoyable collaboration.

I take particular pleasure in talking to students. In my career I have not supervised very many Ph.D. students, but I have had the good fortune of supervising some truly brilliant ones. Maria Prandini, who is now on the faculty at the Politecnico of Milano, was my very first student back in the 1990s. Maria has a calm and deep personality. We still do research together, and I love working with her. Simone Garatti, a student of mine who finished in 2004, has an outstanding mind. He now works at the Politecnico of Milano, but we still meet and do work together on a regular basis. Last but not least, my present student Algo Carè is a talented researcher and a person with an extraordinarily broad culture. I hold many persons I did research with close to my heart. I may come across as being stubborn and wanting to do things my way, which may be true, but I can tell that the way I am has changed over time thanks to my interactions with the people I have worked with during these many years.

Q. What do you find most stimulating in research?

Marco: Research is my life, and I love it. No doubt the thing that excites me most in research is studying and understanding the connections between concepts and ideas in an attempt at unification and abstraction. Through this process we try to gain access to the secret beauty of order. Often things appear separate just because we have not been able to take a perspective broad enough to encompass them in a unifying view. It is quite gratifying when we come to have the broad picture. Let me give you an example. I have been studying adaptive control for many years. My work has been quite technical, things like proving convergence of adaptive schemes using martingale tools, but then you start asking yourself: What is the very nature of adaptation? Is adaptation inherently tied to the time variability of the control law? Does time variability of the environment call for adaptation? And how is adaptive control related to

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nonlinear control? Answering these questions is not just a formal exercise, and I believe that rationalizing ideas of broad scope is likely to have a more long-lasting impact than proving convergence results.

Q. What are some of your present research interests?

Marco: Engineering aims at modifying reality. This is germane to this discipline and indeed sets it aside from all other scientific disciplines. Control engineering is even more unique as control aims at modifying the behavior of existing objects through their interaction with other objects we design and realize, the controllers. Studying control systems, and seeing them in action, is quite stimulating and gives me a buzz. I am currently involved in generalizing a control technique I developed in the early 2000s named virtual reference feedback tuning, VRFT, to make it more industrial oriented and palatable to practitioners.

I also do quite a bit of research in data-based modeling, that is, system identification, and data-based decision making. Here, I try to explore the intrinsic limits posed by the information contained in the data to solve problems in identification, filtering, and prediction. Generally speaking, I believe that many methods we use do not exploit in full the information content carried by the data. By letting "data speak," I believe we can come up with new schemes able to provide us with probabilistically guaranteed results by assuming far less priors than existing methods do. Along this line, I am currently working on prediction schemes based on interval predictor models (IPMs), where the central concept is that reliable prediction of even complex systems is possible through simple descriptors provided the prediction accuracy is tuned to the available information in the data. Another research topic in the same vein is filtering, where I am investigating schemes alternative to the Kalman filter with the goal of furnishing guaranteed estimates that rely on reduced probabilistic priors than with the Kalman filter. It is not easy, and I am encountering difficult technical issues, but it is altogether quite stimulating as the problem of extracting knowledge from data, I reckon, is the most central issue of all science.

Q. What courses do you teach relating to control? Do you have a favorite course?

Marco: I have been teaching a second-year course on classical control and state-space systems for many years, and I also give a course every year on system identification to a restricted cohort of fourth-year students, which covers prediction-error identification methods, Kalman filtering, and even more state-of-the-art topics related to my own research. In addition, I have been teaching graduate courses at various universities on statistical learning, optimization, and adaptive control. You will probably be surprised to hear that among all these courses my favorite is the basic course on control and state-space systems. For a second-year course, the typical length in Brescia is 50 lectures, each of them two hours long, leaving the instructor with plenty of time to interact with the students. It is leisurely teaching. I try to deliver the concepts at an intuitive level first. Take for example the concept of "state," a student can well understand it by making reference to his/her last trip by car with friends—to decide the next destination what he/she needs to keep in mind is where he/she is at present, not how he/she arrived there. Students readily grasp the idea, but what amazes them, at least most of them, is when the next step is taken and the mathematical formalization of the concept is introduced. Using differential equations, the concept of state can be incorporated into mathematics, and this opens new avenues to establish far-reaching implications that are hardly obtainable via nonanalytical approaches. I try to get them to understand that mathematics is a language, as much as Italian or English are, except that mathematics is perfectly structured for developing logical implications. The cycle is closed by touching ground again and by reinterpreting the results in the light of real-life examples. I try this same approach with many other concepts such as reachability, observability, feedback, and combinations of these concepts. When students understand all this, their faces light up, which is the most gratifying moment as an instructor.

Marco and Elena during a trip in Cappadocia.

Q. How would you describe your teaching style?

Marco: I am an old-fashioned teacher in a sense in that I use blackboard and chalk as much as I can. I do not do this for nostalgic reasons; I believe that blackboard and chalk remains the most flexible teaching tool, in that it allows you to adjust to various needs as they arise. In addition, the lecture is more dynamic at the blackboard as you

have to move around. I then complement classes with simulation sessions showing how a control or identification algorithm performs. This is fundamental to get a concrete and operative idea of the methods. For some of the students simulation time is like a bucket of fresh water, they "wake up" from the anesthetic effect of formulas.

Q. Are you an author of any books in the control field?

Marco: I have been writing a book for more than ten years, and I start doubting it will ever see the light! To me, a book represents the "summa" of one's knowledge. But where should one stop perfecting? I do not think I'm good at striking a happy medium.

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

Marco: I like sports, especially tennis and skiing. Some years ago I was chatting with Maurizio Nastasio, an associate who helps me with tutorial classes and who lives in a small village near Brescia. He told me that someone can drive from Brescia to Montecampione, a skiing resort in val Camonica, in one hour. I am originally from Milano, and I still live there on weekends; Brescia is my working city, so apparently I had missed out some of the very fundamental pieces of knowledge about Brescia! Ever since, in the winter I have been indulging in occasionally driving my car to Montecampione during weekdays. You go there, ski three hours, drive back, take a shower, and you are in your office around 2:30 pm; can you imagine anything better?

I also like traveling and visiting places. When traveling I often carry technical problems in my mind, and at times I let my partner Elena know what I am thinking about. You will think I'm hassling her; I have the same doubt, but normally she is kind enough to show an interest in what I say and this encourages me to persevere. Talking to Elena is stimulating, and I also collect some good advice, after all science is a matter of good sense.

Q. Thank you for your comments.

Marco: It was my pleasure.

XIAOHUA XIA

Q. What are the most important factors that lead to your initial and continuing interest in the control field?

Xiaohua: My educational background and the people I met during my professional development and career were the most important factors. I was trained as an applied mathematician, but I took a number of courses in electrical engineering. I believe this had planted a seed for both my theoretical and application interests, and control systems provided a unique platform to develop these two interests. During my postgraduate studies and the early parts of my careers, I met many great people, my mentors, colleagues, and friends, who shared the same vision as me about control. My Ph.D. supervisor, the late Prof. Weibing Gao, opened the initial window for me to peek through and see the greatest milestones of dynamical system modeling and control.

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Q. What are some of your research interests?

Xiaohua: My early research interests are theoretical issues of nonlinear systems: nonlinear observers and noninteracting control of nonlinear systems, in particular. For quite some period of time, I studied the then-popular approaches of differential geometry and differential algebra to nonlinear systems. Since I joined the University of Pretoria, my research has subsequently focused on more application-oriented projects that were very relevant to the industrial and societal needs of South Africa: HIV/AIDS modeling and the associated prognosis studies, modeling and control of heavy-haul trains, and modeling and optimization of energy systems.

Xiaohua Xia, professor in the Department of Electrical, Electronic, and Computer Engineering at the University of Pretoria, South Africa, at Langebaan, West Coast, Western Cape.

Q. As an early researcher to introduce control engineering models in the study of HIV/AIDS, can you briefly summarize the potential benefits that these control approaches bring to HIV/AIDS patients?

Xiaohua: The research of the pathogenesis of HIV has reached a point where control system engineering can play a constructive role. The model-building technique and parameter identification/estimation schemes are extremely useful for immune prognosis.