LUCA ZACCARIAN

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

Luca: I have had the pleasure of meeting several key people who have increasingly inspired my passion for this field. This is a good opportunity for me to thank them all for contributing to my current professional profile. The first person who inspired in me Dilbert's "knack" was my father, who showed me how electronic devices work and taught me about craftsmanship. I chose to study engineering without any idea of what "control" meant, and I first learned about it from Riccardo Marino, who taught my first systems-theory course. The course itself and Marino's passion in teaching it motivated me to continue my master's studies in that direction. At the time, I was an application-oriented student, mostly enjoying experimental nonlinear control applications, and I enjoyed building a prototype of an elastic robot, under the supervision of Turi Nicosia and Antonio Tornambè for my M.S. thesis. A major change in my perspective toward control happened later, during my Ph.D. studies, when I left for a long-term visit to the University of California, Santa Barbara, (UCSB) to work with Petar Kokotovic.

Getting to know Petar was a blessing in my life. His guidance and advice has been a key to many of my follow-up accomplishments. Advised by him, I started to work with Andy Teel, who inspired an abrupt shift of interest toward nonlinear control theory, initiated from collaborating with him on the control of saturated systems. Mathematically encoding a relevant intuition is perhaps the most powerful and fascinating exercise that I learned from Andy, who is still a mentor, a collaborator, and a friend.

Looking back over the past 20 years, I realize that I was inspired by outstanding researchers who shared a joint passion for research and also became good friends. Much of this big family has deep roots in those years at UCSB and the wonderful people that I got to know back then.

Luca Zaccarian next to a test bench of the power-split transmission of Dana Rexroth Transmission Systems in Arco, Italy.

Luca playing guitar with Dragan Nesic and Daniel Liberzon in a Japanese bar during the 2015 IEEE Conference on Decision and Control in Osaka.

Q. What are some of your research interests?

Luca: In a few words, I would say that my research interests are focused in theoretical and applied nonlinear and hybrid control.

More specifically, I feel there are two strong spirits in me: the *applied* one, having its roots in my early robotics background, and the *theoretical* one that emerged strongly after my experience in UCSB and set the tone of my early research activity. The interplay

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between these two spirits has been a fundamental path in my research. My experience is that a challenging practical application can lead to a relevant theoretical problem formulation (perhaps reaching its maturity after a number of years). This is what I call "from practice to theory." Conversely, a solid theory is general enough to apply to a wide range of contexts, thereby inspiring solutions to new applications. This is what I call "from theory to practice."

For example, my interest in saturated control design started with Andy Teel when he was consulting at Newport Corporation about an active vibration-isolation experiment that was prone to saturation problems. Those experimental challenges inspired much of the follow-up theoretical work, which we summarized later in our book on antiwindup design. Meanwhile, I applied many of those theoretical solutions to other applications, such as the control of Tokamak plasmas, the control of open water channels, and, more recently, brake-by-wire systems for motorbikes and control of marine vessels.

Another example of the theory-versus-practice interplay is the Tokamak plasmas application that I was introduced to in 2004. Addressing plasma position and shape control, I came up with the paradigm of dynamic control allocation that can be combined with antiwindup in an integrated control architecture wherein the antiwindup part addresses transient saturation phenomena, and dynamic allocation ensures that the steady-state response comes back to requiring feasible control inputs. That theory is now a subject of intense theoretical research with several colleagues and has been applied to the world's largest Tokamak experiment (the Joint European Torus in Oxfordshire, United Kingdom), in addition to a few of other areas such as hybrid cars and satellite control.

A last area where I believe that this interplay is giving interesting results is the need and the use of hybrid dynamical-systems models (that is, mathematical models whose solutions may evolve continuously, or flow, but also experience instantaneous changes, or jumps). We used this paradigm to address impacting systems with a new intuitive understanding of impacts, as seen from a Lyapunov perspective, but also for better understanding and characterizing the use of resets in proportional-integral control (or more general dynamical controllers) for improving performance. The idea of resets was introduced in 1958 by J.C. Clegg, but it was never fully understood in terms of guaranteed stability and performance until the right theoretical Lyapunov theory was available. This new reset control paradigm is inspiring much of my current theoretical research on hybrid systems and is proving to be very effective in several applications that

Luca with a group of Italians (from left, A. Astolfi, Luca, T. Parisini, P. Colaneri, and E. Valcher) during the VIP dinner of the 2011 joint Conference on Decision and Control and European Control Conference.


Luca with a group of colleagues at a dinner organized by Yoshio Ebihara in Kyoto, a few days after the 2015 IEEE Conference on Decision and Control.

Profile of Luca Zaccarian

- *Current position:* senior researcher, LAAS-CNRS, Toulouse, France; associate professor (part time), University of Trento, Italy.
- *Visiting and research positions:* University of California, Santa Barbara; University of Melbourne, Australia; University of Rome, Tor Vergata, Italy.
- *Contact information:* LAAS-CNRS, 7 avenue du Colonel Roche, 31400 Toulouse, France, zaccarian@laas.fr, http://homepages.laas.fr/lzaccari/.
- *IEEE Control Systems Society experience highlights:* Conference Editorial Board (2009–2013); Board of Governors (2014); associate editor, *IEEE Transactions on Automatic Control* (2011–2016); Student Activities chair (2015–present); associate editor, Electronic Publications: Conference Information (2015–present).
- *Notable awards:* O. Hugo Schuck Best Paper Award, American Automatic Control Council (2001); Fellow, IEEE (2016).

I have been addressing, mostly related to the automotive field. What fascinates me about it is that we have experimental evidence of stabilizers showing a control input exhibiting exponentially diverging branches that are then stabilized by the reset actions.

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

Luca: Until a few years ago I was working at the University of Rome, Tor Vergata, Italy. Among others, I taught a course on experimental robotics wherein the students were asked to code their favorite algorithms to plan the motion of some relatively cheap, five-degree-of-freedom manipulators. The challenge for me was that I was in charge of the teaching and of the lab equipment. The reward for doing the course was that the students had a lot of passion for that experimental course, and I enjoyed teaching such passionate students. Some of the videos that they spontaneously posted on YouTube are still online!

After I left Rome, I joined the LAAS-CNRS in Toulouse, France, as a researcher. I initially enjoyed not having to teach anymore (because of the time commitments) and being able to concentrate on research. However, after some time I started missing contact with the master's students. Later, the opportunity of working part time at the University of Trento in Italy has been just perfect. There I teach a master's course in English, involving linear systems theory and some fundamentals of Lyapunov theory in the mechatronic engineering degree program.

About my teaching style, I like to get to the bottom of the things that I teach, proving also the little details and encouraging the students not to take any statement for granted. My teaching is all blackboard and chalk, mostly with a theorem/proof type of structure, frightening for some students while at the same time inspiring for others. I enjoy teaching a lot, so my lectures are quite "colorful" in terms of colored chalks and in terms of the enthusiasm that I try to convey during my lectures. I suppose that people seeing me teach would agree that I am having fun!

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

Luca: I always felt that control theory remains hidden to the masses. I myself only learned about it about halfway through my university studies. I agree with Karl Astrom's statement that control is the "hidden technology." My impression is that the technological progress is increasing the possibility for the final customer to personalize the "hidden" aspects —the inner control laws. If this process continues, as I hope and expect, in some 10 to 15 years teenagers will be used to playing around with control laws, hacking and modifying internal algorithms of high-tech devices. This will increase the visibility of control theory at the high school level and may attract more attention to our discipline from the broad masses. I expect that this will trigger new research directions that we may call "control for everyone" and a new era where control will be a well-known scientific field.

At that point it won't be as hard to answer the (currently frightening) common question "what area of science do you work in?," typically asked by the person sitting next to you in an airplane, while he/she peeks over your draft paper full of weird mathematical symbols.

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

Luca: My second book is the main monograph that I have been working on in my life. It collects more than ten years of work on antiwindup solutions for systems with input saturation. The idea behind antiwindup is that often you go and talk to an industry and they tell you: "We tuned after six months of work a wonderful controller for this product, and it works extremely well… most of the time. Indeed, if input saturation occurs, that controller malfunctions and induces crazy transients, diverging responses, catastrophic results!" In these cases, industries like the idea of adding an extra piece to their controller, which remains silent until saturation occurs, and then is activated to fix things, but its action fades away as fast as possible once things are back to the normal "unconstrained" regime. This is the antiwindup ultimate goal.

Mathematically, the antiwindup goal is as hard as a bounded stabilization problem with a constraint on the local behavior, which makes it quite challenging. From the practical and industrial perspective, it is a problem

that I find fascinating and keeps inspiring me. I find most effective that you don't redesign a controller from scratch but you inject some small fixes to it, mostly preserving the previous solution, which is a practice that industries really appreciate because their controllers often come with a good deal of past expertise, security, and compliance guarantees, and they don't like to give up on them. I have been applying this paradigm to several industrial contexts, and each application reveals interesting challenges.

The idea that we followed when writing our antiwindup book was to somehow manage to reach the industry by proposing several algorithms that could be used off the shelf, at least in the cases where the windup problems were standard enough to be solvable by adopting a fully constructive design. We intentionally left out any formal statement like theorems and lemmas, despite the fact that our papers are full of them. We thought that this would have given a different perspective to our work. So far, I must confess that we have not received much industrial feedback about it and the book still remains mostly in the hands of an academic audience. Perhaps the state-space tools that we use in the book are not familiar enough to the industrial audience. Perhaps we haven't done a good job of simplifying the derivations to make them accessible enough. Or perhaps we just need to wait a few extra years to see a growth of interest in our techniques.

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

Luca: I like playing guitar and singing. I have been playing music since I was eight years old, and it is a big part of my life that I share with my wife Chiara, and now with our two little kids. Amazingly, when playing a piece of classical guitar I won't remember the positions if I concentrate on them, whereas the music will naturally come out of my hands as long as I don't focus on it but fall into a sort of trance. Chiara says that this is how I practice the use of the right side of the brain. I think that creative research is kind of the same type of exercise. I also like going on mountain hikes or generally strolling around immersed in my thoughts. Searching for mushrooms in the woods is one of my favorite activities that I have been doing since I was about two years old. "Cungo" I would say (instead of fungo, the Italian word for mushroom) when seeing one. I guess already back then my passion for research was building up inside me!

Q. Thank you for your comments.

Luca: My pleasure! Thank you for having me.

» TECHNICAL ACTIVITIES *(continued from page 15)*

Renewable Energy Lab, United States. Van Wingerden is also one of the organizers of the invited session "Control of Wind Energy Systems." In the session "Control in Green Energy—Part I," van Wingerden and Fleming gave an invited talk, "Wind Energy and Controls Research." Several TCPG members actively participated in these sessions as well, with Prof. Lucy Pao from the University of Colorado at Boulder giving several invited talks.

TCPG members participate in many other conference activities, bringing a broader awareness of energy-generation issues to the IEEE community. Kwang Lee from Baylor University is organizing an invited session on power generation at the IFAC World Congress. Fossil-fired power-generation control is typically one of the focus topics of the annual International Society of Automation/Electric Power Research Institute Power Industry Division symposium. Ben Chorpening from the National Energy Technology Laboratory, Pittsburgh, Pennsylvania, is organizing a session, "Emerging Technologies Track, Novel Control Strategies."

Future activities include organizing a workshop on power generation, "Control and Integration of Fossil, Renewables, and Nuclear Power Generation Systems—Recent Advances and Current Challenges," at the 2016 IEEE CDC in Las Vegas. This workshop will present key recent breakthroughs by some of the leading researchers in power generation from all three fuel types and will focus on current challenges confronting the power genera tion field. Several invited sessions were planned during the TCPG meeting at the 2016 ACC.

The are currently several hot topics regarding power generation. Fusion, wind-turbine, and solar-thermal power-generation control are as hot as ever, and clean fossil-generation technologies, such as chemical looping and fuel cells, are slowly coming to fruition. Even the fossil-fired power-plant control has to cope now with the enormous challenges of integrating into a smart grid.

I would like to invite researchers in control and other fields to join the committee and contribute to its activities.

REFERENCE

[1] Annual Energy Outlook 2016. [Online]. Available: http://www.eia.gov/forecasts/aeo/er/index.cfm (accessed June 2016)

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