



Frank Doyle racing on the sailboat *Prevail* (Frank is in the red jacket).

the top-ranked research programs in science and engineering at UCSB.

referee certification and had the chance to officiate at the California State Cham-

My favorite sport for competition is sailboat racing.

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

Frank: Outside of my professional career, I enjoy spending time with my wife, Diana, and our three kids, Sara (17), Brianna (15), and Frankie (13). We enjoy a variety of outdoor activities, including hiking, downhill skiing, soccer, and sailing. I am an avid soccer referee and have officiated approximately 300 matches. I recently completed my national

pionships in 2012. My favorite sport for competition is sailboat racing, and I have been a sailing enthusiast since I was about five years old. I raced on the varsity team in college and continued to race in California, first as a graduate student in the 1980s and then as a professor since 2002. I presently crew on a 52-ft sailboat based in Santa Barbara, and our team has competed in regattas from Los Angeles to Cabo Mexico and from San Francisco to Santa Barbara, and we recently completed the 2012 Transpac Regatta (2250 mi from Los Angeles to Honolulu), finishing second in our division.

Q. Thank you for your comments.

Frank: It has been my pleasure—thanks for inviting me to participate in this interview.

ALBERTO BEMPORAD

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

Alberto: I was perhaps an atypical child in that I enjoyed building my own toys rather than playing with them, considering math and numbers playthings in their own right. This inclination then led to a passion for repairing bikes (some-



Alberto Bemporad, director and professor of control systems at IMT Institute for Advanced Studies Lucca, Italy.

thing I still enjoy today) and soldering simple electrical circuits for my own amusing applications. I was certainly atypical in that I always got great pleasure in doing my math homework as well! By the time I was a teen, this tradition was well consolidated, as I was happier programming my own video games in BASIC on my home computer than actually playing them. This aptitude undoubtedly paved the way to my decision to enroll in electrical engineering (EE) at college. Despite also being very drawn to math and physics, I was

particularly attracted by a fourth year course in nonlinear control and robotics in the EE program, which helped to secure my decision. As I quickly progressed with my courses and exams, receiving very high marks allowed me to win helpful grants every year that I studied, and I discovered that my favorite subject was linear algebra, being fascinated by its mathematical beauty and rigor. To this day, the final exam for this course is my favorite of all time. As I later went on to take courses in electrotechnics, mechanics, and hydraulics, solid mechanics and theory of structures, and electromagnetic fields, what struck me the most was the multiple analogies all of these fields had in common, like the fact you can model complex mechanical or hydraulic systems as equivalent electrical circuits and that theorems

Profile of Alberto Bemporad

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- *IEEE Control Systems Society experience highlights:* associate editor of *IEEE Transactions on Automatic Control*, 2001–2004; chair of the Technical Committee on Hybrid Systems, 2002–2010.
- *Notable awards:* Best master's thesis award "G. Barzilai," IEEE Centre and South Italy section, fourth edition; IEEE Fellow, 2010.

of solid mechanics are very similar to theorems in electromagnetic fields theory. It was no surprise then when I had to choose my major—control systems! The program provided me with the grounds to mathematically understand several of these analogies, in addition to being in fact the most math-intensive track in EE, heavily based on linear algebra, matrix computation, differential equations, and complex analysis. The track also gave me the opportunity to improve my programming skills on an IBM-compatible computer in a recent environment called PC-Matlab.

As I approached the end of my studies, I came across a new undergraduate course called Optimization, which I had never heard of before but really enjoyed. Through the course I realized that conceiving a new algorithm, programming it, and discovering that it was producing the results I was expecting was really satisfying! I was lucky enough then to have the opportunity from Prof. Edoardo Mosca to write my master thesis in MPC (model predictive control), a subject that brings together optimization with control theory. I since have not abandoned the field, as it was not only the topic of my Ph.D. thesis but has been a constant in my research up until today.

When I started my research career, I had many doubts. The encouragement of Prof. Alberto Tesi (a real example of scientific creativity, math-

ematical rigor, and human qualities) really helped me in making my decision. So I decided to follow my passion and enjoy myself doing something I really loved, in spite of the relatively low salary as a Ph.D. student at the University of Florence, motivated also by the possibility of spending a year in the United States as a visiting student, which I did in St. Louis at Washington University under the guidance of Prof. T.J. Tarn.

My journey to becoming a professional academic researcher from being a newly minted Ph.D. with a passion for research was undertaken during my postdoc at ETH Zurich in Switzerland, under the guidance of Prof. Manfred Morari. I will always be grateful to him for having been a role model for me, teaching me the art of being a researcher in control engineering.

I am also indebted to Dr. Davor Hrovat of Ford Motor Company, who for a long time gave (and still gives) me the opportunity to work together with him and his team on real control engineering problems. These experiences contributed dramatically to get my critical sense of the impact theoretical ideas can have in practice.

Q. What are some of your research interests?

Alberto: Generally speaking, posing and solving new theoretical issues that have a direct applicability in practical problems intrigue me. Currently,

together with my research group in Lucca, I am studying novel algorithms based on dual fast gradient-projection methods to solve quadratic programming and linear MPC problems that are extremely easy to code, require only basic arithmetic operations, and whose worst-case numerical complexity can be estimated quite accurately. This was triggered by a tight interaction I am having recently with Dr. Samir Benani of the European Space Agency, who has asked me to address the concrete issue of being able to implement MPC in real aerospace hardware to solve guidance, navigation, and control problems. Another subject I am currently intrigued by is stochastic MPC, due to its abilities to address rather complex control problems that arise in financial engineering, in the management of smart grids and bidding on electricity markets, in the management of drinking water networks, and in power management of hybrid electric vehicles, just to mention a few of the problems that I have been recently working on.

I think the approach of identifying new theoretical control issues that are motivated by a specific application problem, abstracting the general problem, and obtaining general results that are applicable to many other different problems (including the starting problem!) greatly helps in minimizing our ever-present gripe regarding the gap between control theory and control engineering practice. Criticism must constantly accompany intuition while doing research ("does what I'm doing make sense?"), a practice that is often easy to forget when diving into the mathematical details.

I am also continually more drawn to applying MPC methodologies to unconventional domains. For example, I tend to get intrigued in developing optimization models to solve (sometimes weird) everyday-life decision problems, something I really enjoy! My new location at IMT Lucca is helping me with widening the application of control ideas, in that I am the only control person in an interdisciplinary

environment with management scientists, economists, theoretical computer scientists, and statistical physicists. I was also the only control person in the Engineering School of Trento, surrounded by structural, civil, mechanical, and hydraulic engineers, which has also contributed to widening my appreciation of the impact control and optimization techniques can have in several domains.

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

Alberto: Before joining IMT Lucca, which is one of the few public Italian academic institutes that only offers doctoral degrees, I had mainly taught undergraduate courses in linear control systems, except for periodic short courses on MPC and hybrid systems for Ph.D. students and industry. In preparing undergraduate control courses, rather than following traditions established over decades I always tried to reshape my courses in an attempt to modernize what students learn, given that the presence of packages like Matlab or Python have changed the tools an engineer has available today. This approach led me to largely deemphasize classical frequency-domain techniques in favor of methods based on state space. I also enjoy teaching numerical optimization courses.

When I teach, I try to provide self-contained mathematical proofs and to explain, using easy words and analogies or examples, what is not written in textbooks. I found that this helps students in understanding the main concepts that are sometimes hidden behind the math. In evaluation questionnaires, students regularly highlight that I am demanding, but appreciate my technical rigor, my ability to instill a passion for the subject within them, and my ability to transmit concepts that they are able to fully grasp. They also appreciate my diligence in always posting all of my lesson slides on my Web site!

I am also indebted to Dr. Davor Hrovat of Ford Motor Company, who for a long time gave (and still gives) me the opportunity to work together with him and his team on real control engineering problems.

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

Alberto: Control theorists have a lot to teach. While traditional (single-loop) control problems are probably too mature at this stage to generate new wider opportunities, I find that the approach of control theorists, that is, the rational way of building dynamical models with a clear role of inputs, outputs, and states, gives us the ability to address many new theoretical and application challenges. But this does not come for free; we cannot stay closed rigidly in our own established domain. Rather, it requires understanding and mastering new techniques (such as large-scale optimization, parallel programming, complex networks, big-data analysis, and many others) and spending the time delving into new application domains to understand what control ideas can bring as an added value. I remember investing about a year reading books and papers to understand the basics of quantitative finance before being able to propose a stochastic MPC algorithm to solve option-hedging problems. (By the way, feedback control and numerical optimization are surprisingly rather underexploited concepts in quantitative finance!)

Q. You have recently accepted the position as director of IMT Institute in Lucca. Do you think that your new role, and the extra responsibilities that it will no doubt entail, will be detrimental to your research?

Alberto: The obvious answer would be yes: directing a dynamic research university like IMT would seemingly undoubtedly subtract time

from my schedule that I usually dedicate to research. Indeed people have also told me that I was too young to become director of the institute (in fact, I am currently the youngest rector of an Italian public university), and that this would have interrupted and reduced my research productivity. The reality is that, while I might physically spend less time on pure research throughout my tenure as director, my new position actually puts me in a privileged position in terms of new interaction possibilities I have with researchers in other fields, which will ultimately help me in formulating new research challenges for control theory. In my new position, I can facilitate and actually instigate meaningful joint research projects with people in other fields, as I lead the institute forward in cutting-edge interdisciplinary research.

As the institute is relatively small, composed of about 35 faculty members (most of them young assistant professors), all dedicated to research and completely uninterested by internal academic politics, I still have time to spend doing research. I have a wonderful research group of young and very talented postdocs and assistant professors and high-quality Ph.D. students that IMT is consistently able to attract (for just the last Ph.D. call, for example, we received over 2000 applications, from all over the world, for 36 positions). IMT offers four interdisciplinary Ph.D. tracks, including a control systems curriculum, which is embedded in the computer, decision and systems science track and shares graduate courses taught by colleagues and visiting professors of economics, management science, theoretical

computer science, statistical physics, numerical analysis, and optimization.

In a way, leaving my appointment at the University of Trento a year and a half ago and coming to IMT, a relatively small and new university, was a leap of faith. However, I am confident that it is precisely for these characteristics of IMT, which favor flexibility that more consolidated academic institutes do not necessarily enjoy, that I will have the opportunity to

ensure that the institute continues to undertake research at the forefront of the scientific frontiers, meanwhile forming excellent young researchers, especially within the field of control!

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

Alberto: Free time has always been very limited for me since I started college, and now that I have two small

children, ages one and three, it is almost zero! I still try to find a little time for my hobbies: repairing bikes, do-it-yourself projects (mainly building rustic furniture from scrap wood), riding my Vespa scooter, playing the guitar, and hiking in the Appennini mountains in Tuscany, whenever possible.

Q. Thank you for your comments.

Alberto: Thank you for the opportunity!

CHANGYUN WEN

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

Changyun: When the Cultural Revolution ended in China, I was a senior high school student. At that time, four modernizations (modernization of agriculture, industry, national defense, and science and technology) were officially launched in China. There were various kinds of propaganda promoting the four modernizations and explaining how to realize them including the application of modern technologies. The terms automation and automatic control fre-

quently appeared, and their concepts and applications were also explained using simple intuitive words. I was impressed and attracted by automatic control. In China, students choose their specializations before being admitted to universities for undergraduate studies. Automatic control at Xi'an Jiaotong University was my first choice, and I was admitted with that choice. In the third year after entering the university, I attended my first control course, which was on classic control. Then in Year 4, I studied several additional subjects in control including instrumentation and process control, modern control theory, introduction of optimal control, and linear system theory, in addition to doing a final year project in the control area. I read a few technical papers

to carry out the project. I was fascinated by the application aspects of control theory exposed in the papers and successfully completed the project. On the other hand, it was difficult for me to completely understand the theory, and I felt what I had studied was insufficient. I decided to pursue my further study in the area. So after graduation in 1983, I continued searching and reading published papers related to control. Adaptive control, which had been one of the hottest topics, attracted me. I then made my mind to undertake my Ph.D. study along the direction of adaptive control under the supervision of Prof. David Hill at the University of Newcastle, Australia. Since then, I have continued my interest in adaptive control.

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Q. What are some of your research interests?

Changyun: My main research interest is in the area of adaptive control. Over the past 27 years, I have been working on robust adaptive control, decentralized adaptive control, and backstepping-based adaptive control for both linear and nonlinear systems. One of the first problems that was solved is the establishment of global stability for decentralized adaptive control of continuous-time and discrete-time, linear and nonlinear systems without constraint on subsystem relative degrees, by using various approaches. My research group also worked on adaptive control



Changyun (center) with four of his former Ph.D. students, Dr. Zhengguo Li, Dr. Jing Zhou, Dr. Wei Wang, and Dr. Wenxiang Xie, at the Fifth IEEE Conference on Industrial Electronics and Applications in Beijing, June 2010.