Beginning in December 2003, each issue of *IEEE Control Systems Magazine* features researchers, educators, and practitioners of control technology. In this issue, we feature two newly appointed professors along with brothers in control. Silvia Ferrari is an assistant professor at Duke University, where she uses neural network methods to develop intelligent aircraft flight control algorithms. Clarence Rowley is an assistant professor at Princeton University, where he is involved in control and fluid dynamics with applications to noise control, engine efficiency, and fish locomotion. Next we feature the brothers Esfandiar Shafai and Bahram Shafai, who developed a common interest in control. As you will read, the brothers' interests diverged slightly when one chose mechanical engineering and applied research while the other chose electrical engineering and more theoretical interests. We hope you enjoy these interviews and look forward to them in future issues.

Computers Learning to Fly

CSM: *As an undergraduate at Embry-Riddle you had a chance to study aeronautical engineering. Can you recall when your interest in control began?*

Silvia Ferrari is with the Department of Mechanical Engineering and Materials Science, Duke University, Durham, North Carolina, USA.

Silvia: It's interesting that you should ask that. I was always interested in both mathematics and engineering, and I looked for a major that would allow me to combine the two. But just when I thought I had found a good combination by choosing aerospace engineering, I read Bryson and Ho's book on optimal control for a special project, and right then and there I knew I had found my field.

CSM: *Now that you teach control courses at Duke, do you view yourself as a fairly traditional instructor, or do you try innovative techniques?*

Silvia: Actually, I'm fairly traditional. I'm a big believer in the classic chalk blackboard and hand-written-notes approach. However, I try to stimulate the students' imagination by giving homework assignments that are multidisciplinary and fairly open ended. For example, I wrote a homework problem for a graduate class on intelligent systems and controls where I ask the students to use tree diagrams to illustrate how dynamic programming searches a reduced space of solutions in a Markov decision process. Then, the students must use the same approach to show the computational savings brought about by approximate dynamic programming, using Howard's formulation from 1960. Also, some day I would like to try oral exams in my graduate courses, hoping it won't scare the students away.

CSM: *Your current research relates to neural networks and adaptive control. Did you choose this research area, or was it an extension of your advisor's interests?*

Silvia: First let me say that I was extremely fortunate to have Prof. Rob Stengel as my advisor. We always shared similar interests and work ethics, and he is the role model I would like to follow in my academic career. Prof. Stengel introduced me to my research area of neural adaptive control, and our collaboration led to new applications in aerospace and biomedical applications.

CSM: *So where do you see your research headed toward in the near and far future?*

Silvia: I plan to continue focusing on methodologies for adaptive control and machine learning. I'm especially interested in expanding my research into areas such as information science and neuroscience, where I see great potential for reciprocal contributions. These fields have challenging control problems, which will surely inspire new approaches for dealing with complex systems. In the near future, I hope to make further contributions to neural-network control of aircraft by extending the approach I developed in my dissertation to morphing-wing aircraft. I'm also working on automating sensor-network management by combining the normative and descriptive approaches that have developed somewhat independently in the control and computer science literature.

CSM: *Do you find it difficult to explain your research to nontechnical friends?*

Silvia: I find it a little difficult. Usually I find that what works best is to explain that I'm trying to get computers to reason more like people, for instance so that a computer can learn how to fly a plane. Of course, I get a lot of horrified looks when I say that!

CSM: *So what do you do to keep busy when you're not working on your lectures or your research?*

Silvia: I ski and windsurf whenever I can, usually when I visit Italy. In Durham, I enjoy jogging, biking, and reading, mostly philosophy and psychology essays.

Imitating Fishy Behavior

CSM: *You were an undergraduate student at Princeton and now you teach there. How does it feel to be teaching in classrooms where you were recently a student?*

Clarence: At first, it felt a little strange, particularly interacting with the other faculty who were my own teachers just a few years ago. But after a few weeks the strangeness wore off, and now I find it really useful, as I can relate to the students well. For instance, I know that if I schedule a take-home exam during house parties, I'm not going to be very popular.

Clarence (Clancy) W. Rowley is with the Mechanical and Aerospace Engineering Department, Priceton University, Princeton, New Jersey, USA.

CSM: *Your chosen area of research is modeling and control of fluids. Do you feel at home in both fields?*

Clarence: I'm lucky that I had two fantastic advisors in graduate school, Tim Colonius in fluids and Richard Murray in controls, who sent me to lots of conferences in both fields. As a result, I do feel pretty much at home in both communities. Now the problem is finding the time to keep attending both sets of conferences!

CSM: *A fluid is a pretty wily system to control. In a nutshell, can you describe what you feel are the challenges and promise of controlling a fluid?*

Clarence: Some of the applications I find most exciting are reducing acoustic noise from aircraft, improving efficiency of gas turbine engines, understanding fish-like locomotion, and manipulating fluids at very small scales. These applications present many challenges, but my personal viewpoint is that there are two main ones: actuator development and modeling. Sensors are not as big an issue, since the fluids community has been taking fluid measurements for over a century. Consequently, the focus of the flow control community has been largely on actuators. Now people are starting to use more sophisticated control techniques and ask questions about fundamental performance limits, for which good models are needed.

CSM: *Your Web site has a picture of yourself in front of some mountains. Where was the picture taken, and are you a climber?*

Clarence: That picture was taken on the summit of Cathedral Peak, in Yosemite National Park. I started getting interested in climbing when I was a graduate student at Caltech, and one of my professors (Chris Brennen) would drag me down various canyons on the weekends. He taught me to rappel using the trial-by-fire approach, and then we started tackling some semitechnical peaks, like Cathedral Peak and the Grand Teton. I still enjoy climbing, but there aren't as many mountains in New Jersey.

CSM: *What do you do when you're not working on your research or teaching your courses?*

Clarence: Sleep! No, actually the pre-tenure life isn't that bad, and I do find time to pursue my main hobby, which is music. I sing in a choir on weekends and play the piano whenever I have the chance. I also joined a rowing club this summer, so now I wake up at 5:30 to row on Lake Carnegie—a very Princetonian thing to do.

CSM: *Do you have a "hero" in control and/or fluids? What about a mentor?*

Clarence: Hmm, there have been so many people who have shaped my life, and that I admire tremendously, that it's hard to choose a single hero or mentor. In graduate school, I had three mentors: my advisors, Tim Colonius and Richard Murray, as well as Jerry Marsden, and they continue to be mentors to me. Also, my colleagues at Princeton have been wonderful mentors for the past two years, especially Naomi Leonard, Phil Holmes, Lex Smits, Yannis Kevrekidis, and Mike Littman.

Brothers Across the Atlantic

CSM: *You're not twins, are you? Has one of you ever been mistaken for the other?*

Esfandiar: No, we're not twins. But sometimes it happens that we are mistaken for the other, as if we were twins. As a matter of fact, an unnamed *IEEE Control Systems Magazine* editorial board member came up to me at the IFAC SYSID 2003 conference and told me he hadn't seen me in a while. In fact, I had never met him before!

CSM: *It's unusual for two siblings to be working in the same academic area. So, I'd really like to know: Who influenced whom? Or, was there a single source of inspiration that led both of you into the control field?*

Bahram: Since I am the older brother, one might think that I influenced my younger brother. However, we made our choices independently. To elaborate more, let me give you some background.

From early childhood my brother was always busy with mechanical devices. For example, he used to open watches to find out how they work. Since he couldn't understand the mechanisms, he often became frustrated. He eventually found out how they work when he was in

high school, and his skills allowed him to fix things around the house. On the other hand, I was always interested knowing how an electron moves through a wire and I learned a lot by building electrical circuits in high school. After I completed high school, I was planning to come to the United States for higher education. However, our father insisted that we pursue our university education at The Swiss Federal Institute of Technology (ETH) in Zurich, where he studied chemical engineering and graduated shortly after World War II. So, we followed his path and both ended up at ETH.

I studied in the Electrical Engineering Department of ETH and my brother joined the Mechanical Engineering Department. Later on, we independently took courses in control systems. Initially, we didn't know that control systems would be our concentration. The major source that inspired me was the most delightful and interesting lectures of Prof. Mohammad Mansour, the former head of the Automatic Control Institute.

CSM: *When it comes to research and teaching, are there any obvious differences between you? In other words, is one of you more applied or theoretical than the other?*

Esfandiar: Indeed, since mechanical engineers are traditionally more applied than electrical engineers and because of my experience in reverse engineering (taking things apart), I can claim that I am more applied, but Bahram is much stronger in the theory.

CSM: *Can you please tell me a little about your research and its applications?*

Esfandiar: My research interests are in system identification, robust control, and adaptive control. Currently, I am leading a research project funded by the Swiss Federal Office of Energy. The goal of this project is to develop a new control approach for heat pump heating systems. The heating energy has to be delivered into the house in optimal portions, distributed optimally throughout the day with respect to the weather forecast, the most efficient operation of the heat pump, low-tariff periods, and cut-off periods of the electrical power (a Swiss specialty), while still guaranteeing the desired indoor temperature. We implemented a model predictive control (MPC) algorithm in a commercially available controller that worked successfully in a single-family house. Right now we're developing an online identification algorithm to identify the parameters of a house model used in the MPC. During and for a few years after my dissertation at the Measurement and Control Laboratory of ETH, where I'm still working as a research associate, I was involved in research projects on the emulation of vehicle dynamics on an engine test bench, engine control involving a catalytic converter, control of hybrid cars, and identification of helicopter parameters. Recently, my interest has been directed toward modeling and control in financial engineering.

Esfandiar Shafai (left) is with the Measurement and Control Laboratory, The Swiss Federal Institute of Technology (ETH) in Zurich, and Bahram Shafai is with the Electrical and Computer Engineering Department, Northeastern University, Boston, MA, USA.

CSM: *How about you, Bahram?*

Bahram: My main research interests include robust control, observers, Kalman filtering, signal processing, and adaptive control. Most of my publications are related to parameter space methods in robust stability and control. I've worked on observer theory including proportional-integral observers for loop transfer recovery and fault detection. My research has been supported by companies such as MITRE, Draper Labs, and Linear Technology. On the application side, I investigated the problem of mass imbalance in magnetic bearing control systems, where I used an adaptive force balancing approach to reject the synchronous vibration caused by mass imbalance. I also applied robust control design methods for various DC-DC converters. In my teaching, I'm involved with the capstone design course where I'm helping students integrate control methods in a number of projects.

CSM: *Have you ever published jointly?*

Bahram: A few years ago, an elderly gentleman knocked on my door and asked me to help him understand some results he obtained in his basement laboratory. He showed me a nonlinear circuit he had drawn along with a table of measurements collected from the circuit. He was claiming that his circuit could measure the phase margin of a linear system in a feedback loop more accurately than existing signal/spectrum analyzers. He told me that he wanted to see his invention published quickly, especially at his age. At the same time, my brother was visiting me in Boston on his vacation. So, we both forgot about the vacation and used the time to analyze the circuit. My brother simulated the circuit using SIMULINK,

while I did the theoretical analysis. The final outcome was a paper published in the *IEEE Transactions on Instrumentation and Measurement* in 1994. So, we have a joint paper with Mr. Dantowitz, who is active today and just recently approached me with another wonderful idea (stay tuned).

CSM: *What is your opinion about the education (particularly control systems) in Europe as compared to United States?*

Esfandiar: The impression I have is that, in the field of control systems, the education in Europe is strongly application oriented, while in the United States the emphasis is placed on the theory. However, in recent years I have also recognized a trend in the United States with more emphasis on applications. In Europe (particularly in Switzerland) the students are involved with industrial projects, which are embedded in their term papers. Bahram tells me that at Northeastern and many other universities around the United States the emphasis is on practice-oriented education. In his capstone design course, students can choose projects based on their co-op experience, advanced topics proposed by faculty involved in research centers, and projects sponsored by industry. The interesting fact is that the capstone design course is a multidisciplinary experience since most projects have a control system component.

CSM: *What advice would you have for younger control researchers, especially graduate students?*

Bahram and Esfandiar: Control is an exciting area with many venues for practical applications. We both believe that control researchers are faced with a hybrid world in which knowledge of one area alone is not sufficient. One should expand his/her knowledge to understand the modeling aspects of a particular system needed to characterize the conflicting goals that arise in control. Graduate students in control learn that theory and practice are complementary, and it is essential to enhance both of them for successful completion of the M.S. and Ph.D. degrees. You should believe in what you are doing, stay focused in your research, be aware of new results reported by other researchers, establish links with your research group to exchange ideas, never give up on your goals, and listen to your advisor. Another important issue is to improve your communication skills and written reports delivered to the outside world.

Finally, we are both very proud and fortunate to be a part of control community with wonderful people orchestrating the smooth process of research and development in the exciting field of control systems.

CSM: *Finally, when you are not doing research or helping mysterious visitors analyze exotic circuits, how do you spend your time?*

Esfandiar: When I was younger and had more time, I used to play soccer every weekend with my colleagues. When Bahram was living in Switzerland, we played on the same team. Three years ago I discovered inline skating. Not far from my home, there is a very scenic river with a paved path running alongside. When weather permits I skate 10 miles after work. Sometimes my son Ramin (19) or my daughter Yeganeh (17) joins me, making it even more fun. In addition, my wife Doris and I have taken courses in salsa, merengue, and bachata dancing. Last but not least, I also enjoy cooking. Every time our friends are invited I spoil them with delicious Iranian dishes.

Bahram: I spend most of my free time with my family, which includes my wife Soheila, my daughter Ghazaleh (22), and my son Shahin (17). I'm also involved in soccer, ballroom dancing, and community service. I still play in a soccer league, coach a club team, and referee soccer games for all age groups.

CSM: *Hmmm, if someone didn't know you were brothers, it wouldn't be hard to guess! Best wishes, and thank you for the interview!*

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