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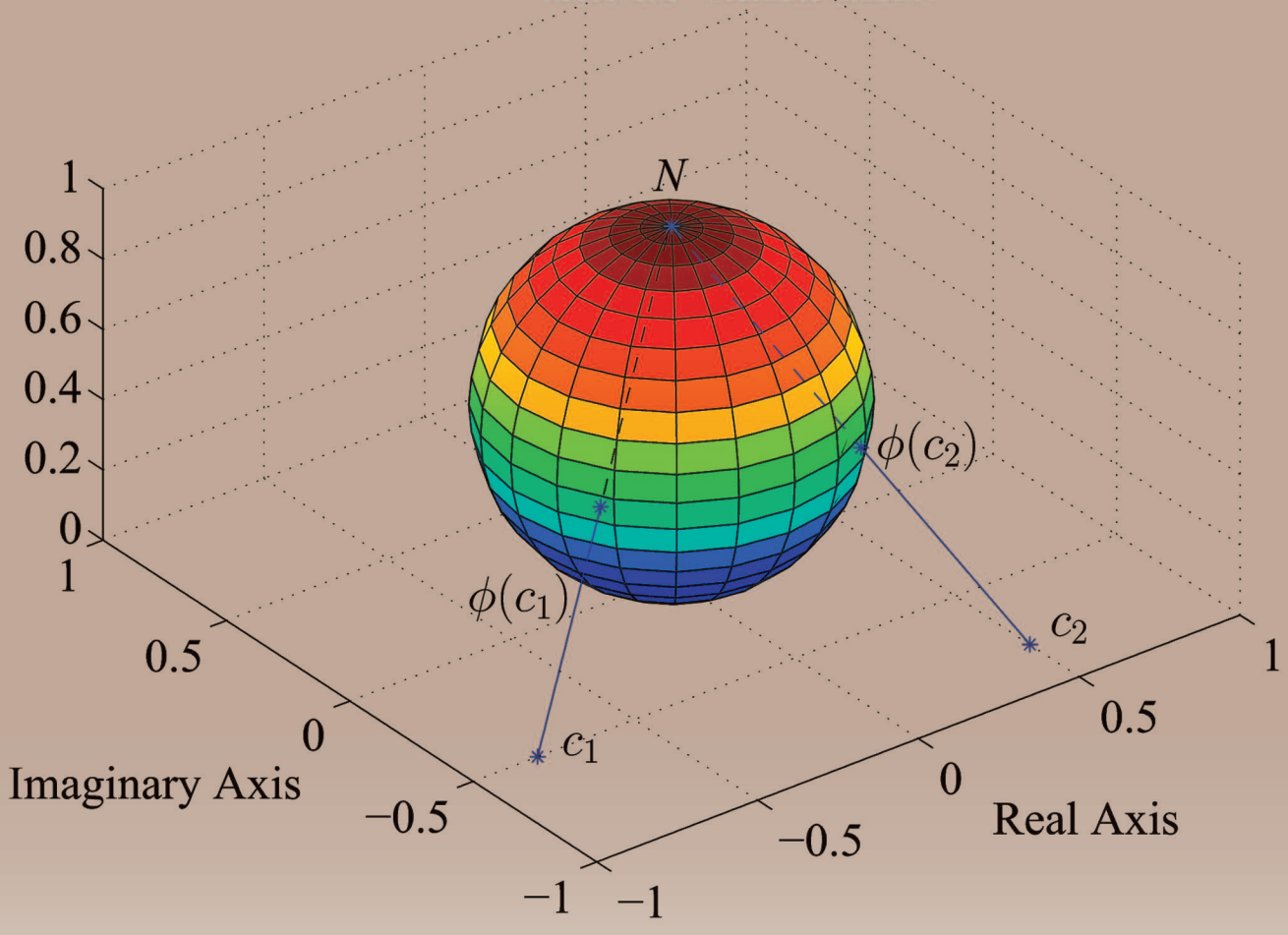

Control Education

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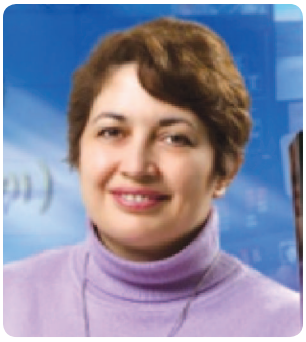
IEEE

NAIRA HOVAKIMYAN



Naira Hovakimyan, professor of mechanical science and engineering and university scholar at the University of Illinois at Urbana-Champaign.

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

Naira: I graduated from Yerevan State University in Armenia with an M.S. degree in theoretical mechanics and applied mathematics in 1988. My M.S. thesis adviser, who was a former student of Nikolai Krasovskii, suggested that I pursue my Ph.D. studies in Yekaterinburg (formerly Sverdlovsk), where one of the strongest control groups at the time was working under the supervision and leadership of Nikolai Krasovskii. That was the time period when the former Soviet Union was collapsing, and given the amount of various uncertainties with the collapse of the empire, I decided to pursue my Ph.D. studies in Moscow rather than in Yekaterinburg (Moscow was closer geographically and easier to reach). In either case, it was clear that my dissertation was going to be on differential games. I joined the Laboratory of Controlled Mechanical Systems at the Institute of Problems in Mechanics of the Russian Academy of Sciences and completed my dissertation in three years under the supervision of Arik Melikyan (1944–2009).

During my three years of Ph.D. studies in Moscow, I had the pleasure and privilege to interact with some of the strongest groups in the world and to present my work at Moscow State University and the Institute of Automation and Control Processes of the Russian Academy of Sciences and to many other prominent groups. It may sound strange today, but back then I was doing these presentations using a blackboard and white chalk. I remember clearly my first conference presentation back in 1990, in the VII Union Conference "Control of Mechanical Systems," where I first met Prof. Krasovskii, Prof. Andrei I. Subbotin, and many other distinguished leaders in our field.

In 1992, after my graduation, I returned to Armenia to start working in the Academy of Sciences. Later, I obtained two fellowships and spent more than a year at the University of Stuttgart, working on the theory of chaos with John Argyris, and about a year at INRIA, Sophia Antipolis, working in robust control and team problems in collaboration with Pierre Bernhard.

In 1996, I received the best paper award for a young investigator in the VII ISDG Symposium in Japan, where I met Prof. Josef Shinar from Israel, who later in 1998 invited me to the Technion to work with him on differential game methods for missile guidance, and there I learned about the opportunity to join the group at Georgia Institute of Technology to work on the stability of adaptive flight control systems. This was a crucial point in my life, as I was, for the first time, challenged to understand and estimate the epsilons and deltas in terms of numbers, as just having a mathematical proof was not enough. It was really an eye-opening experience for me to find out that the actual numbers and the decibels matter more to engineers than to mathematicians. I took the challenges seriously and developed a new view of the world during those years. In 2003 I joined Virginia Tech, and I started working on L_1 adaptive control. The continued success in applications keeps our interest in controls field so far alive.

Q. What problems are you working on?

Naira: Today we work on many different problems, ranging from abstract mathematics to rigorous experimentation on various platforms. We have ongoing work in geometry, stochastic systems, robust adaptive control, networked systems, flight control development, unmanned systems, automation and situational awareness, and problems in robotic surgery.

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

Naira: I teach both graduate and undergraduate courses that include system dynamics, signal processing, classical control, nonlinear control, and robust and adaptive control. Most of all, I enjoy teaching the graduate course from my book. I would love to teach functional analysis one day from Kolmogorov's textbook that I had in my junior year, but I understand that in a mechanical engineering department this may never happen.

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

Naira: I see the future of controls more in its integration with various disciplines and better use of technology. We have to admit that advances in technology open tremendous opportunities to redefine some control problem formulations and to look at those formulations in a novel way. Today we see rapid development in the integration of engineering with health care, sociology, psychology, and other disciplines. It is apparent that feedback solutions can bring great insights into these disciplines. As thought experiments, an interesting perspective is to formulate grand challenges of control on an abstract level. One grand challenge could be, "Can we reduce the space and time?" For example, "Can we reach the sun within one day, collect samples, and come back?" I do not see this happening in any near future, but it can be viewed as a grand challenge. We can formulate similar formidable challenges also on the nanoscale.

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Q. You are the author of the book *L_1 Adaptive Control Theory*. Can you briefly explain the essence of L_1 adaptive control?

Naira: The essence of L_1 adaptive control is in the decoupling of the estimation loop from the control loop, which makes the approach different from existing adaptive control solutions that suffered from the certainty-equivalence nature of the architectures. The fast estimation loop in L_1 architectures approximates the inverse map, required by internal model controllers. Hence, from the perspective of the input–output map, L_1 architectures achieve the performance and robustness guarantees of internal model controllers (IMCs), but their architectural versatility allows for a number of *systematic* modifications to address measurement noise, delays, saturations, and other nonlinearities. Also, the fact that there is no need to compute the inverse map explicitly not only relieves some of the restrictive assumptions (smoothness, etc.) that otherwise have to be imposed on the system but also offers a computationally tractable method with straightforward practical implementation. For example, in some complex systems, where performance specifications are given by a desired nonlinear dynamical system, implementation of IMC-like controllers requires solving partial differential equations, while the fast estimation loop of L_1 architectures approximates this hard-to-compute solution sufficiently closely (subject only to CPU limitations) within the bandwidth of the control channel.

Profile of Naira Hovakimyan

- *Current position:* university scholar, Schaller Faculty Scholar, and professor of mechanical science and engineering, University of Illinois at Urbana-Champaign.
- *Visiting and research positions:* University of Stuttgart; INRIA Sophia Antipolis, France; Georgia Institute of Technology.
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- *Honors and awards:* AIAA Mechanics and Control of Flight Award, 2011.

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

Naira: My interests and activities have changed quite a bit with age. As a child, I was very attracted to chess and studying foreign languages. At the age of 14, I scored third place in a chess competition in town. Thanks to the opportunities to work in Germany and France, I was able to perfect my knowledge of French and German to be sufficiently fluent in speaking and e-mailing. To relax, I enjoyed knitting and could easily spend a few hours a day with knitting needles. Today I enjoy more connecting with true friends and being in their company, away from work, listening to my favorite music, reading my favorite authors, swimming, and traveling.

Q. Thank you for your comments.

Naira: Thank you for the interesting and thoughtful questions that helped me to reconnect with the past.

TOSHIHARU SUGIE

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

Toshiharu: When I was an undergraduate student in the Department of Mechanical Engineering at Kyoto University, my supervisor recommended that I read a yellow book, *Linear Multivariable Control: A Geometric Approach*, by Murray Wonham. The book was really beautiful. I was so fascinated by its clear vision and concise language. That was the first time that I really became interested in control theory. In graduate school, I encountered two more books. One book was Thomas Kailath's *Linear Systems*. I enjoyed learning about the structure of linear systems. The other book was *Feedback Systems: Input–Output Properties* by Charles Desoer and M. Vidyasagar, which impressed me with its depth, beauty, and compactness. The essence of norms, small gains, and passivity was given in a quite clear way. These books motivated me to work in the control area.

Toshiharu Sugie, professor in the Department of Systems Science at Kyoto University.

Q. How did you start your research career?

Toshiharu: My first work was related to inverse systems and was published in *Automatica*. At that time, I was interested in the characterization of system input/output structure in terms of algebraic conditions. However, after working in industry for a few years, I realized that the real world was not so simple, and it would be necessary to control systems with uncertainty. Since then, my main interests

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