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

Pablo: Twenty years ago, I wrote a monograph with one of my first graduate students on minimum-entropy control. More recently, Brian Ingalls and I coedited the book *Control Theory and Systems Biology*. We compiled some examples of how control theory could be used to study biological systems. Over the last ten years, I have been compiling a comprehensive set of notes for my biological signaling class, which I would eventually like to turn into a textbook. Unfortunately, I am a slow writer so progress on this is sluggish—I also have too many other things that take priority.

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

Pablo: I love traveling—I have been to about 40 countries in my life. I have played the drums since I was a teenager, and this is one of my favorite hobbies. In the last few years, I have also done a lot of hiking and backpacking. I have two sons who are both quite active in the Boy Scouts. Four years ago, their troop was in desperate need of an adult to lead them. I reluctantly volunteered, not because I thought that I was particularly well suited (I had never been a big fan of camping), but they needed someone badly. I have grown to enjoy the position quite well.

Q. Thank you for your comments.

XIAOBO TAN

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

Xiaobo: It was fortuitous how I got into the control field. When I graduated from high school, I knew I would be going into some engineering field. However, I had no clue exactly what field would suit me. My second-oldest brother, who was then a sophomore majoring in civil engineering at Tsinghua University, told me computer science and automation were two of the "hottest" majors at Tsinghua. I gathered that automation would involve computers anyway, so it seemed smart to choose the former, which I did. I was pleased with my decision, since I saw the rigor and versatile applications of control theory. While completing my master's thesis on thyristor-controlled series compensation of power systems, I realized my passion in control system research. I then joined the University of Maryland to pursue my Ph.D., under the supervision of Prof. John Baras and Prof. P.S. Krishnaprasad. I was heavily influenced by their appreciation of mathematics and physics. My dissertation topic was on the modeling and control of hysteresis in smart material actuators. The Ph.D. training extensively exposed me to material physics, which had a lasting impact on my later career.

Xiaobo Tan (left) and his Ph.D. student, Osama Ennasr, next to the gliding robotic fish "Grace" on Higgins Lake, Michigan.

Q. What are some of your research interests? How do you characterize the style of your work? How do you disseminate your research to a broader community?

Xiaobo: The modeling and control of systems with hysteresis remains a core research interest of mine. Over the years, I have collaborated with Prof. Hassan Khalil on extending nonlinear control tools to hysteretic systems. I am also interested in the modeling, control, and applications of emerging smart materials. For example, my NSF CAREER project focused on the model development and control design for electroactive polymers, also known as artificial muscles. Much of our attention was paid to physics-based, control-oriented modeling, so that powerful tools from systems and control theory could be used to advance the understanding, development, and practical applications of these materials.

Another research interest of mine is bio-inspired robots and their application to underwater sensing. In particular, my lab has a major research thrust on fish-like robots, spanning the end-to-end cycle of robot design, development, modeling, control, and real-world applications. My work in this

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area was prompted accidentally by an outreach effort, where we tried to demonstrate the applications of artificial muscles by using them as underwater propulsors. A team of middle and high school students created a robotic tadpole with a wiggling artificial muscle tail, which marked the beginning of our sustained effort in underwater robotics. I feel such serendipitous developments are partly the reason why our profession is so fascinating. We are currently exploring schools of gliding robotic fish for monitoring harmful algal blooms and tracking invasive fish species, where, aside from other interesting problems, theory and algorithms for distributed estimation and control are of immense relevance.

Our work emphasizes both analytical and experimental elements. I believe experimental work, especially field experimentation, is not only instrumental in assessing the performance of theory under realistic conditions but also inspiring at times. Insight from experiments often motivates new and relevant research questions in dynamic modeling and control design.

My students and I participate in many community outreach activities. We recently concluded a ten-month robotic fish exhibit, Robofish Rendezvous, at the Michigan State University (MSU) Museum, which illustrated a number of engineering concepts such as feedback control. Included in the exhibit was live interaction with a temperature-sampling robotic fish, where the robot uses feedback from a webcam to navigate to any target point set by a visitor. I have also been heavily involved in the development and management of an NSF-funded Research Experiences for Teachers site program at MSU.

(From left) Xiaobo, Sean Andersson, P.S. Krishnaprasad, and Fumin Zhang at the 2016 IEEE Conference on Decision and Control.

Xiaobo observing class implementations of the new curriculum developed by Research Experiences for Teachers participant Wendy Johnson at Lansing Catholic High School.

Profile of Xiaobo Tan

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- *IEEE Control Systems Society experience highlights:* chair, Finance, American Control Conference (2015); liaison, IEEE Nanotechnology Council (2012–2014); Conference Editorial Board (2007–2010); guest editor, *IEEE Control Systems Magazine*.
- *Notable awards:* Michigan State University Teacher-Scholar Award (2010); NSF CAREER Award (2006); Fellow, IEEE (2017).

Q. What courses do you teach relating to control? How would you describe your teaching style?

Xiaobo: I teach a junior-level control course, which primarily covers root locus and frequency response techniques. Since the course does not have a lab, I strive to make the students appreciate the relevance of the subject by discussing the critical role control plays in various cool technologies, such as the ocean-barge landing of the SpaceX rocket. I also regularly teach three graduate-level courses on adaptive control, multi-agent control, and smart material sensors and actuators. These courses all contain a creative component, individualized course projects, to help students gain and sharpen their research skills.

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» PEOPLE IN CONTROL *(continued from p. 27)*

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

Xiaobo: We live in an increasingly "smart" world—think about smartphones, smart homes, smart cities, and many other smart systems concepts we hear every day. Strides in sensing, actuation, communication, and computation—all essential elements of a feedback control loop—have made it possible to create systems that revolutionize our daily life, which presents an exciting opportunity for the control community. While the community has made tremendous advances in fundamentals, such as networked control and collaborative control systems over the past two decades, now is the time to see the fruition of these efforts in much larger and more complex real-world contexts. The latter will involve not only myriad engineering and computational elements but also less familiar elements such as human behaviors and public policies. With the systems perspective in our blood, I think control engineers have a unique role to play in the current "smart movement." It is challenging but gratifying at the same time because of its immense societal impact.

Q. You have coauthored one book. What does this book cover?

Xiaobo: I wrote *Biomimetic Robotic Artificial Muscles* with Kwang J. Kim, Hyouk Ryeol Choi, and David Pugal. The book presents a comprehensive, up-to-date overview of several types of electroactive polymer materials that cover developments in material processing, actuator design, modeling, and device and robotic applications. In particular, two of the chapters illustrate how a systems-theoretic approach can be adopted to facilitate the modeling and control of electroactive polymer actuators.

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

Xiaobo: My favorite activity outside of work is swimming. I actually log my completion times for different "events," to track how my human hydrodynamics gets optimized (or not) over time. I also enjoy spending time with my kids.

Q. Thank you for your comments.

Xiaobo: You are very welcome. I really appreciated this opportunity.